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Memoir upon the Stability of Revetments, and of their Foundations. By M. PONCELET, *Chef de Bataillon du Génie. Translated from "No.* 13 *du Mémorial de l'Officier du Génie," by Captain* JOHN SANDERS, *Corps of Engineers.*

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Formulas and Tables for the Case of Mean Earth and Masonry.

15. The preceding considerations naturally lead us to investigate whether it would not be sufficiently exact, in practice, to substitute, at least to a certain extent, the formula (m) for the method of calculating the thicknesses of revetments by the rigorous equation (g) of number 7, which reaches the sixth degree (8) when we substitute for M and u their values in e; in each case a suitable value should be given to the factor or coefficient δ, by which the moment M is to be multiplied. But, to prevent uselessly complicating the necessary calculations for establishing the comparison between the results of one and the other method, we will suppose $\theta = \alpha$, or the exterior slope of the parapet to be parallel to the natural slope of the earth, which is ordinarily the case. Considering, moreover, in the same view, the case of mean earth and masonry, for which $\alpha = 45°$, tang. $\alpha = 1$, $p = \frac{2}{3}p'$, and in recollecting the conventions established in number 1, from which we have

$$a = \frac{h}{H}, x = \frac{e}{H}, m = \frac{b}{H}, u = \frac{h'}{H+h} = \frac{h+b-e}{H+h} = \frac{a+m=x}{a+1}$$

we can transform, without difficulty, the expressions (a) and (b) of number 3 into the following:

$$M = \tfrac{1}{6} p \left[3 + 3u^2 + 2u^3 - 2\sqrt{2}\,(1+u^2)^{\frac{3}{2}} \right] (H+h)^3$$

$$P = \tfrac{1}{2} p \,(\sqrt{2} - \sqrt{1+u^2})^2 (H+h)^2$$

which gives for the mean length of the lever arm of pressure, the expression

$$\frac{M}{P} = \tfrac{1}{3}(H+h) \frac{3 + 3u^2 + 2u^3 - 2\sqrt{2}\,(1+u^2)^{\frac{3}{2}}}{3 + u^2 - 2\sqrt{2}\,\sqrt{1+u^2}}$$

which can again be put under the form

$$\frac{M}{P} = \tfrac{1}{3}(H+h)(1-u) + \tfrac{1}{3}(H+h) \frac{u + 3u^3 - 2\sqrt{2}\,u^2\,\sqrt{1+u^2}}{(1+u)^2}$$

in multiplying the numerator and denominator of the fraction by $3 + u^2 + 2\sqrt{2}\,\sqrt{1+u^2}$. The second term of this expression for the lever arm will always be a small fraction of the first term, which represents (fig. 1) one-third of the height BH, or $H + e - b$, against which the pressure P is exerted.

16. Giving, in effect, to u the various values which it can receive from $u = 0$ to $u = 1$; that is to say, from h' or GH = 0, to $h' = H + h$, or GH = GB, which supposes BH zero with reference to BG, or CG infinite; we shall form the following table, in which the values of the ratio of $(u + 3u^3 - 2\sqrt{2}\,u^2\,\sqrt{1+u^2}) : (1-u)(1+u)^2$, being that of the second to the first term of the above expression for the value of the lever arm of pressure, are represented by

$$U : \left[= \frac{u + 3u^3 - 2\sqrt{2}\,u^2\,\sqrt{1+u^2}}{(1-u)(1+u)^2} \right] :$$

Values of u.	Values of U.	Values of u.	Values of U.
0.000	0.0000	0.400	0.0889
0.033	0.0029	0.500	0.0751
0.050	0.0420	0.600	0.0591
0.100	0.0685	0.700	0.0430
0.200	0.0943	0.800	0.0273
0.250	0.0978	0.900	0.0146
0.260	0.0980	0.950	0.0046
0.300	0.0966	1.000	0.0000

$$\left[\frac{M}{P} = \tfrac{1}{3}(H + e - b)(1 + U) \right]$$

17. It will be seen by this table that the greatest value of U is below one-tenth, and corresponds very nearly to $u = 0.26$; so that, in

taking the arm of the mean lever of pressure equal to $1.05\,(H + h)\,\frac{1}{3}\,(1-u) = 0.35\,(H+e-b)$, the error will not exceed one-twentieth; the second member of this equation is equal to 0.35 of the height BH, against which the pressure is exerted.

If we wish to obtain results always slightly above, though differing very little from, the true ones, we should take $M = P.\,\frac{1}{3}\,1.098\,BH = 0.3666\,P.\,BH$ for all the values of H and h. But it is evident that the coefficient of stability δ, adopted as the factor of M in the equation of equilibrium (g) of number 7, should vary with every hypothesis assumed, although only by a very small quantity.

18. Taking with M. Français, for point of comparison, Vauban's revetment of ten metres high, with a mean load of a parapet two metres high, and supposing that the foot of the exterior slope of the earth should extend to the outer face of the wall, we shall have (7) to determine δ the equation of equilibrium

$$\tfrac{1}{2}\,p'\,H\,(e^2 - \tfrac{1}{3}\,n^2\,H^2) + \tfrac{1}{3}\,p\,(e-b)^2\,(e + \tfrac{1}{2}\,b) = \tfrac{1}{3}\,\delta\,P\,(1 + U)\,BH$$

in which $n = 0.2$, $H = 10$ metres, $e = 3.6$ metres, $p = \frac{2}{3}\,p'$, $b = \frac{1}{5}\,H = 2$ metres, and $u = \dfrac{h'}{H + h} = \dfrac{0.4}{12} = \dfrac{1}{30}$, $BH = 11.6$ metres, which gives $\delta\,(1 + U) = 1.9173$, $\delta = \dfrac{1.9173}{1.0029} = 1.912$, by observing that in the foregoing table $U = 0.0029$ answers exactly to the value of $u = 0.0333$ or $\dfrac{1}{30}$. If we should suppose, *a priori*, that the mean lever arm of the pressure is equal to 0.35 BH, or $U = 0.05$, we ought, on the contrary, to take $\delta = 1.826$, &c.

19. It will follow from this, on the hypothesis of mean earth and masonry, and of the coefficient $\delta = 1.912$, that we shall have, for calculating x, the proportional thickness of the revetments, (15,) the equation

$$(n)\quad \begin{cases} x^2 + \frac{4}{9}\,(x-m)^3\,(x + \frac{1}{2}\,m) \\ = 0.425\,(\sqrt{2} - \sqrt{1+u^2})^2\,(a+1)^2\,(x+1-m)\,(1+U), \end{cases}$$

in which we shall substitute the values of U given by the above auxiliary table, for each of the particular values attributed to a, m, x, and u, (15) in recurring at need to the interpolation by proportional parts, or, otherwise, by tracing a continuous curve, having the valves of u for abscisses, and those of U for ordinates.

20. It is thus that we have formed by the method of successive approximations, the following table of the values of x, which are made on the hypotheses of $m = 0$, $m = 0.2$, $m = x$, embracing nearly all cases occurring in practice. For which hypotheses the equation (n) becomes respectively:

$$x^2 + \tfrac{4}{3}x^3 = 0.425\left[\sqrt{2} - \sqrt{1+u^2}\right]^2 (a+1)^2 (1+x)(1+\mathrm{U})$$

$$x^2 + \tfrac{4}{3}(x-0.2)^2 (x+0.1) = 0.425\left[\sqrt{2} - \sqrt{1+u^2}\right]^2 (a+1)^2 (x+0.8)(1+\mathrm{U}),$$

$$x = 0.652\,(\sqrt{2} - \sqrt{1+u^2})\,(a+1)\,\sqrt{(1+\mathrm{U})},$$

the corresponding values of u being:

$$u = \frac{a-x}{a+1},\ u = \frac{a+0.2-x}{a+1},\ u = \frac{a}{a+1}.$$

In this table we have also inserted:

1st, the values of x, which are deduced from M. Français' equation (l), which, from the foregoing notation and hypotheses, becomes

$$(o) \qquad x = 0.262\,(a+1)\,\sqrt{a+1};$$

2d, the values of x furnished by formula (m,) or

$$(p) \qquad x = 0.285\,(a+1),$$

the coefficient of which 0.285 has been calculated in such a manner as to reproduce, on the supposition of $\mathrm{H} = 10$ metres, $h = 2$ metres, or $a = \frac{1}{5}$, the thickness of a vertical revetment of the same stability as that of Vauban, which thickness is 0.342 of H, or of its height.

3d. In fine, that which is given by formula

$$(q) \qquad e = 0.202\,(a + 0.89)\,\mathrm{H} + 1.24 \text{ metres},$$

this formula is deduced from Vauban's rule for demi-revetments, by the method of transformation of profiles, which will be given further on, but which supposes the transformed vertical wall to have a berme equal to $\frac{1}{5}$ of its height H.

It will be recollected, moreover, (6) that, in the case of figure 2, the foregoing equation (n) should be replaced by its corresponding one (k) of number 9, which gives here

$$x = \sqrt{\tfrac{1}{3}\frac{0.3281\,(a+1)^3 + (a+m)^3 - m^3}{a+1.5}}$$

the values of which should, consequently, be substituted for those which are deduced from equation (n) or its derivatives, whenever $h < e - b$, or $a < x - m$; which corresponds to $a < 0.415$ for the case of $m = 0$, or no berme, and to $a < 0.104$ for that of $m = 0.2$, or of a berme equal to $\frac{1}{5}$ H.

These limits will be indicated in the fifth and sixth columns of the following table, by horizontal lines drawn under the quantities.

Comparative Table

Of the Thicknesses of Vertical Revetments sustaining high embankments, deduced from Formulas (*n*), (*o*), (*p*) and (*q*), relative to ordinary earth and masonry.

Value of a or $\frac{h}{H}$	Deduced from the profile of Vauban, or equation (*q*)	From Formula (*o*)	From practical formula (*p*)	From exact form'a (*n*) berme b'ng		
				Zero.	Equal to 0.2H	Eq'l to the thickness.
	metres.					
0.0	0.180H + 1.24	0.262H	0.285H	0.270H	0.270H	0.270H
0.2	0.220H + 1.24	0.345H	0.342H	0.336H	0.342H	0.326H
0.4	0.261H + 1.24	0.434H	0.399H	0.399H	0.405H	0.358H
0.6	0.301H + 1.24	0.530H	0.456H	0.477H	0.457H	0.377H
0.8	0.341H + 1.24	0.633H	0.513H	0.544H	0.504H	0.391H
1.0	0.382H + 1.24	0.751H	0.570H	0.605H	0.540H	0.405H
2.0	0.584H + 1.24	1.361H	0.855H	0.795H	0.655H	0.425H
3.0	0.786H + 1.24	2.096H	1.140H	0.892H	0.717H	0.435H
4.0	0.988H + 1.24	2.929H	1.425H	0.957H	0.755H	0.442H
10.0	2.200H + 1.24	8.568H	3.135H	1.109H	0.839H	0.452H
20.0	4.220H + 1.24	25.213H	5.985H	1.171H	0.872H	0.456H
Infin'e	Infinite	Infinite	Infinite	1.243H	0.927H	0.461H
1	2	3	4	5	6	7

Observations and Consequences.

21. This table leads to several important consequences. It will at once be seen, by the last three columns, that the thicknesses of revetments increase proportionally to their heights, when the inverse ratio a of these heights to those of the loads, does not change. Besides, the numbers at the bottoms of these columns show that the thicknesses of revetments converge to a finite, and, indeed, a small, limit; while, on the contrary, the height of the load approaches infinity with reference to that of the masonry—a fact worthy of being remarked, and entirely analogous to the one presented by M. Petit for the thicknesses of the buttresses of arches.

In fine, the comparison of the numbers of these same columns, which belong to equal values of a, leads to another fact, which would appear odd, if we were to overlook the reciprocal influence of the weight of the earth, CIH, (fig. 1,) which rests directly on the wall, and the pressure of the other earth against it, along the section, CH, formed by the upward prolongation of the plane of the back of the wall: it is, that the existence of a slight berme, which, for light loads, with reference to ordinary revetments, gives a sensible excess to the thickness of the masonry, will, on the contrary, lead, for high embankments, exceeding four-tenths of the height of the wall, to a diminution of the thickness, which constantly increases with the height of the load, and the width of the berme.

22. Now, if we compare the results of the second, third and fourth

columns of the table, with those which correspond to them in the fifth, sixth and seventh columns, of which the first two express, on our hypotheses, the true thicknesses of vertical revetments, with such widths of bermes as comprise nearly all practical cases; we conclude from it, that, at least for mean earth and masonry:

1st. The rule of Vauban gives thicknesses which surpass as much more those which it would be sufficient to adopt for the stability relative to rotation, as the height H of the demi-revetment, is smaller with reference to the height h of the load of the parapet; but it can also happen that it might give too slight thicknesses for great values of H.

2d. The formula (o), which, for very small loads, gives rather short results, afterwards leads to excess in the thickness, which excess rapidly increases with the ratio, a, of the height of the load to that of the wall; and if, with the view of lessening its influence, we substitute, as is ordinarily done, for this first height, taken simply from the middle of the superior slope of the parapet, a less one, we then fall into arbitrary results, without preserving the certainty of being always above the true dimensions.

3d. The empirical formula $e = 0.285\ (H+h)$, gives thicknesses which, although a little too great for small loads, are generally comprised between those of the fifth and sixth columns, as long as the height of the load does not materially exceed that of the wall. Moreover, in no case can it lead to errors which exceed one-seventeenth of the total thickness, if we do not extend its application beyond this limit, and if we only consider the width of the berme to be the same as is usual in fortifications.

4th. In fine, none of the abridged rules nor formulas in question can answer in the case of very wide bermes, or of revetments, when the exterior slope of the parapet does not extend so as to cover a certain quantity of the top of the wall; the excess in the thicknesses given by these formulas over the true ones, increases as much more rapidly as the height of the load is itself greater with reference to that of the scarp.

23. We see from this that the formula $0.285\ (H+h)$, notwithstanding its extreme simplicity, gives, in fact, less uncertain thicknesses than those got from the formula of M. Français; and these results, except in the specified case of very great loads or wide bermes, can be adopted with confidence, if it is allowable to admit, as is sometimes done in the application of formulas, that the earth and masonry are usually such as are called mean (15).

Now, there does exist, for one and the other, very marked differences; also the relative density and friction play so important a part in the thicknesses of revetments, that it would be exposing ourselves, at times, to serious mistakes, not only in adopting a like hypothesis, but perhaps in further admitting, without previous verification, within assigned limits, the exactness of the more general formula (m) of No. 13—the coefficient δ of which formula ought, evidently, to be taken so as to fall back upon the preceding one, on the hypothesis of

$a = 45°$, and $p = \frac{1}{3}p'$; which gives simply, for the case of rotation: $\delta = 2.13$, and

$$(r) \qquad e = 0.845 \text{ tang. } \tfrac{1}{2}\, a \sqrt{\frac{p}{p'}}\,(H+h), \text{ or}$$

$$x = 0.845 \text{ tang. } \tfrac{1}{2}\, a \sqrt{\frac{p}{p'}}\,(1+a).$$

24. Moreover, we are not ignorant that experienced engineers have believed that they might, for cases without superincumbent loads, or with very slight ones, adopt the rule which consists in taking, generally, the thickness of retaining walls equal to one-third of their height, (see numbers 84, and following, of this section;) but this rule, which agrees approximately with that deduced from Vauban's mean profile (20), which is generally considered as the type of the most exact proportions between the power and the resistance, leads, evidently, to excess of thickness in the case of light earth and very dense masonry, as it can also, on the contrary, compromise the solidity of constructions.

Let one, in fact, read, in the "*Annales des Ponts et Chaussées,*" year 1831, pages 62 and 349, two very short articles, the one by M. Navier, the other by M. Gayant, concerning a very interesting discussion which arose upon the thickness to be given to the wall of the quay of the outer port of Dieppe; and it will be seen that it is absolutely necessary, in certain cases, to take into consideration the nature of the earth and masonry, if one wishes to shun the inconveniences in question, and which are inherent to every invariable and empirical rule of the kind which we have just noticed, without even excepting that deduced from the profile of Vauban.

(To be continued.)

Mr. Vignoles' Lectures on Civil Engineering, at the London University College.

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The tastes and speculations of the last fifteen years have been so exclusively devoted to railways as the fashionable mode of internal communication, that canals have been almost lost sight of; and it is now nearly forgotten by the modern speculator, though it may be interesting to the young engineer to be informed, that, fifty years ago, the mania for constructing canals and improving river navigation was as great, even if not greater, than the enthusiasm displayed very recently about railways. Parliament was then deluged with applications to grant acts of incorporation for canal companies; the press teemed with canal publications, the shop windows were filled with canal maps and sections, and the papers and periodicals with advertisements and paragraphs on canalization.

Canals appear to have been duly appreciated in ancient times, and used for the purpose of drainage, irrigation, supply of water, and nav-

igation. In his former introductory lecture he alluded to the canal of Xerxes, at the foot of Mount Athos—an attempt which is stated to have been renewed by the Roman emperors in later ages. A canal navigable for large boats was constructed by the Ptolemies between the Nile and the Red Sea, though it is doubtful whether the state of engineering skill in those days permitted an actual junction to be made; this grand navigation was re-opened by the caliphs in the seventh century. Traces of it are still existing, and its termination in the most easterly branch of the Nile was discovered by M. Boutier, in 1707, and is still open. Under the enterprise of the present ruler of Egypt, it may yet fall to the lot of an English engineer to re-open this magnificent canal. Herodotus assures us that the Nile was in itself, or by lateral canals, navigable by the ancient Egyptians for 500 miles above Alexandria, and the Delta of the Nile was formerly, like modern Holland, filled with canals. The Romans made more than one canal in England; the most remarkable was that called the Caerdyke, which united the river Nene, a little below Peterborough, with the river Witham, three miles below Tiverton; it was forty miles long, and, fifty years since, appeared distinct enough, and must have been originally very deep; and what led to the impression that this canal was used for the purpose of internal communication, was, that there was a continuation of this canal from Lincoln to the Trent, above Gainsborough, by the Foss Dyke, which is at the present time a fine, navigable canal, though, in former times, it had been repeatedly filled up and gone into disuse. It is believed, on good authority, that by these two canals, the favorite colony of the Romans at York received their chief supplies of grain. The canals of China have always excited great interest since the description given of them by the Jesuit missionaries; their accounts, as far as regards the Great Canal running from north to south, (connecting, except at one short portage, Canton and Pekin,) have been completely confirmed by modern travelers, particularly by Barrow, who traveled the whole length. Should the existence of the numerous lateral and other canals over the rest of the country be confirmed, of which there is little reason to doubt, it will sufficiently explain the non-existence of anything like good roads, and the almost total absence of wheeled carriages for goods, to which the diminutive and bad breed of horses in China, no doubt, contributes. There is, however, a wide field opening in that country for the exercise of the skill of an enterprising engineer, since that ingenious people are as yet ignorant of the modern lock for their canals, and, when two canals meet, the difference of the level is sometimes from fifteen to twenty feet, and the boats are hoisted from the lower canal, up an inclined plane of smooth masonry, by capstans, and slide down another into the upper canal. The Professor stated it would lead him too far to go much into the history of canals; but he must allude to the great canals and inland water communication of the Mogul country, in the East Indies, made by the emperors 500 or 600 years since, for which the natural features and vast rivers of Hindostan afforded great facilities, and rendered lockage unnecessary; and, indeed, roads were unknown, and may be considered as still

wanting, all over India, excepting our recent military roads. This country presents a vast field for the civil engineer. Of all the canals of modern Europe, he would only notice two remarkable instances: J. Perry, an English civil engineer, was employed by Peter the Great, in the beginning of the last century, to design and execute several canals, in which the German military engineer, (Brockel,) who had at tempted them, had entirely failed; Perry's designs were subsequently completed by Peter's successors. The canal of Trolhatta, in Sweden, the difficulties of which had long baffled the engineers of that country, was finally completed by the skill of the late Mr. Telford, whose engineering resources were equally displayed in the design and execution of the Caledonian Canal. Many remarkable instances of success in making an imperfect river into a good navigable stream, might be quoted, both in Europe and North America, and which present instructive instances to the young engineer. The improvement of the river Liffey at Dublin, and the river Clyde in Scotland, are good examples. The improvement of that vast inland gulf, the Shannon, is now in the course of execution, after several years of most detailed and elaborate inquiries, estimates, surveys, and careful examination, the accounts of which may be studied with great advantage to both the experienced and the young engineer. Upwards of half a million sterling is to be expended on this truly national undertaking. The learned professor then entered into a long account of the probable original ideas for the application of iron to roads, commencing with the wooden railways used in the collieries on the banks of the Tyne, near Newcastle, above two hundred years ago; he then showed that the waste of timber led to the idea of covering wood with plates of iron, and ultimately to the present point of perfection—wrought iron rails—the introduction of which into general use does not extend further back than thirty years.

In the ensuing lectures he should endeavor to illustrate the following points—1st. The principles on which railways should be laid out under various circumstances of traffic, and topographical feature. 2d. The comparison of different systems of inclinations, or gradients. 3d. The analysis of the advantages of various breadths, or gauges. 4th. The illustration of the different modes of forming the railway proper, or upper works. 5th. The investigation and explanation of the great works of construction, as peculiarly found expedient in forming railways. 6th. The practice of framing estimates, and the necessary details connected therewith. 7th. The consideration of the various modes of working railways by animal and by mechanical power, locomotive and stationary. 8th. The inquiry into the working expenses and annual charge on railways; and concluding with a summary lecture, in which the general features of the course will be given, and drawing such prominent inferences as might be most useful and interesting. The other branches of internal communication, as well as the various and numerous subjects connected with the theory and practice of a civil engineer, must be taken up on other occasions. Reserving, then, the elucidation of the details under the several preceding heads for the class room, he would proceed to make

a few general remarks. Of these, the most prominent and most important, in his judgment, and most to be impressed upon the mind of those about to enter the profession of a civil engineer, was that connected with the great excess of actual expenditure, in the construction of railways, over estimates; for not only has that unfortunate, and almost invariable, occurrence brought discredit on each concern so affected, but it has paralyzed, and will long continue to paralyze, the most honest and well-grounded schemes for further internal communication in general, and of all improvements, the cost of which is dependent on the engineer; and though each case ought to be tried and judged on its own merits, the public confidence appears gone, and the capitalist observes with a sneer, "You engineers are all alike; we can trust none of you." Now, without shrinking from his own individual share of the odium thus cast upon the profession, as far as it may truly be deserved, the Professor denied the general and sweeping imputation; and he called on the directors of public companies, in justice to themselves, to their subscribers, to their own engineers, and to the public in general, to publish such details as would exonerate his profession, and leave it charged with no more than what was attributable to it. He called upon his brother engineers to follow this out, by furnishing their quota of information. Let the public in general know these details as matters of railway statistics of the highest interest—let the profession know them as matters of precedent of the most valuable kind—and let the capitalist be undeceived as to his present impressions of mistrust. Quite independent of any financial difficulties—quite independent of any standing orders or regulations of Parliament—a man might as well cry "mad dog" as talk of a new railway speculation, or a water-work, or, indeed, any public undertaking, where the function of profits is a certain known quantity, but dependent on estimates which are considered visionary, because "all engineers are alike in this respect." Let, then, the young engineer mark well the bitter lesson the oldest engineers are now learning—let them cause the most assiduous inquiry into the details—the most unremitting toil in gathering information—storing their minds, exercising their memories, practising their hand, and working out their calculations—let them remember that, by working drawings, by models, and by every *a priori* means of unceasing investigation, they must "first and truly calculate the cost" of what in future life they may be called upon to undertake. If the matter be ever so trifling, they must not shrink from the truth, or attempt to disguise it from themselves, still less from their employers. Let them never have it said of them that they had whispered among themselves, "Oh! it will never do to tell the directors what the work will cost, or it will never be entered upon"—a remark which he had heard fall from an eminent engineer; nor let them indulge in the vain hope of future fame, by taking as their text the observation attributed to another engineer of the very highest and well-deserved reputation—"A century hence there will be no one who will ask what this work cost; they will only inquire who did it."

He begged to repeat, then, what he stated at his first introductory

lecture, that the constant maxim the young, as well as the old, engineer should keep before him, is—"That the success of an engineer, in this country of private enterprises and individual exertions, depends, not upon the beauty, or the cost, of his constructions, or as mere works of art, but on their success as profitable and mercantile speculations." They must not suppose this to be an ignoble maxim; it must be followed out to its true results, and then they would find that prudence, caution, economy, judgment, and the highest intellectual gratification, follow closely in its train; for, to apply the words of Mr. Booth, the intelligent secretary of the Liverpool and Manchester Railway, and one of the fathers of the modern railway system—"The contemplation of what is passing in England, (alluding to the first cost of railways,) must not be without its lesson; for, in all countries, and under all circumstances, it is an object worthy of a statesman, to prevent the reckless waste of the national means, and to give a right direction to the public expenditure." And shall it be said that it is not equally worthy of an engineer? What are the aggregate subscriptions of associated and incorporated bodies of individuals but great portions of the "national means," which should not be wasted by the statesman or by the engineer? What are the monies invested in railways but a part, and, in the United Kingdom, a most important part, of the "public expenditure?" And is it not at once the duty, as it ought to be the pride, of an engineer, to give that expenditure a "right direction?" Let the maxim he had laid down be duly followed out, and that duty would be accomplished. The learned Professor continued by stating that, even at the risk of having motives attributed which he should be unworthy of public or private estimation if he entertained for a moment, he would call the attention of the student to an instance of great expenditure on railways. The perfect completion, in the manner contemplated, of the internal communication by railway from London to the Sussex coast, a distance of little more than fifty miles, will amount, in the aggregate, to nearly four millions sterling. Is not that a reckless waste of the national means? Is that a right direction of public expenditure? Will not the public, in some way or other, pay for that?—the subscriber, or the traveler, or both? To quote the words of an intelligent and experienced railway man—"With such results before us, would it not be almost criminal not to endeavor to secure the advantages of a better system?" The average cost of the railways in England has been very nearly £30,000 per mile. The cost of future lines must not be more than one-half of that sum, or it may be considered that there is an end to the extension of the railway system. The Professor stated that it would be his attempt to explain, in the course of his lectures, his ideas that such a reduction in the expense might easily be made, and he would show that they were founded upon practical experience. The profession would be greatly aided, and the public vastly benefitted, if the railway companies and their engineers would publish the detailed accounts he had asked for, to serve as a beacon, for which all would be very grateful; and it was his deliberate opinion and recommendation, that, if they would not do so, Par-

liament ought to give the railway department of the Board of Trade powers to enforce such returns.

The total amount of capital invested in the railway speculations of this country is probably little short of £50,000,000, and the total extent of lines about 1700 miles—most of which are now completed. This may be said to be the creation of the last fifteen years. The total length of navigable canals in Great Britain is nearly 2500 miles; they were chiefly formed in the last forty years of the preceding century. The capital invested in this branch was about £20,000,000, with an annual expense of about 50*l.* per mile. In addition to canals, there are about 1500 miles of navigable rivers. The turnpike roads of England and Wales are stated, in official returns, to be nearly 20,000 miles in extent, executed at an expense of at least £20,000,000, and maintained at an expense of about £1,750,000 per annum, and all formed within little more than a century, exclusive of other highways, in length about 100,000 miles, with an annual expense of 12*l.* or 13*l.* per mile, or 75*l.* per mile, for maintenance. The extent of executed railways in the United States of America appears to be about 4000 miles, executed within the last fifteen years, at a cost of about £8,000,000, or about £5000 per mile; most of them are single lines, and it is stated that the average net income has been about five per cent. per annum. The extent of railways in Belgium is now about 200 miles, executed at a cost of rather more than £1,500,000, or about £8000 per mile; most of these are single lines, and have all been executed within the last ten years.

The average annual expense of maintaining the railways of England, (exclusive, of course, of moving power, carrying and managing establishments, &c.) appears to be from £200 to £300 per mile, per double way; but on the Dublin and Kingstown Railway, where the system of longitudinal timbers for the upper works has been completely carried out, the same heads of expense are now reduced to less than 50*l.* per mile per annum, with a locomotive traffic over that railway as great, if not greater, than over any one in Great Britain. The average expense of the canal maintenance in this country seems to be about 50*l.* per mile per annum.

The Professor concluded by stating that he would close his somewhat desultory discourse by calling attention to the fact, that the first elements of the amelioration of internal improvements, he would not say internal communication, which arose in this country, date from the period of the introduction of the Poor Laws into England, the effect of which has been to compel the rich to find employment for the poor, or to support them, and thus has been carried out the great principle of self-dependence, in separate districts, to work out their own improvements. Certain it is, that, from the passing of the act of Elizabeth, which instituted a legal maintenance for the destitute, and, by making mendicity a crime, swept the hordes of beggars, idlers, and sorners, from the face of the land, this country took a start, and, overtaking in improvement the other states of Europe, then far in advance of her, has since pursued that successful and continued march of amendment of her internal communication, which forms so remarka-

ble a feature of England, proving her wisdom, and proclaiming her prosperity. He begged that, with his previous cautions, the students would remember that the agent for the carrying out of such improvements, past and to come, has been, and he trusted long would continue to be, the civil engineer.

(To be continued.)

Facts and Observations on Four and Six Wheel Engines.

By JOHN HERAPATH, ESQ.

[Continued from Page 47.]

It will be seen that I have been on thirteen of the Great Western Railway engines. They certainly are fine, powerful engines, and are able to attain very great speeds, with loads that many other engines would find a difficulty in drawing at even moderate velocities. I have heard, in one case, of ten miles having been done by one of them in nine minutes, or *at the rate of* 66½ *miles per hour.* Their large boilers and capacious cylinders give them a power which no other engines possess, and their lofty 7 feet driving wheels enable them to use this power with great advantage at high speeds. But, on many of the new engines, I observe they have only 6 feet driving wheels. Whether that arises from the alleged difficulty which the 7 feet wheels sometimes experience in starting their loads, and clambering up the two inclines, especially the Box, I am unable to say; *but it is a fact on which no doubt exists, that, in getting up inclines with heavy loads, small wheels have a decided advantage over large.* There are cases, indeed, in which a large wheel would not move a load with which a small wheel would trip off merrily. But, with such a load as a large wheel can take well, and at a high speed, there can be no question of the advantage being all on the side of the larger wheels. Upon this line, I understand, it is found that the working of the large wheels is manifestly more economical.

The platform of the Great Western locomotives, in comparison to the platforms of the other companies' engines, is like the quarter-deck of a first rate line of battle ship; and the lofty, square, and roomy fire boxes are exceedingly comfortable for the men, who can get behind them, almost entirely screened from the wind and weather, and still keep a good look out. In consequence of the great breadth of the gage, they have also been enabled to place a platform, by which the men can walk round the engine, while going on, and do anything that is wanting. Had these engines a little sheet iron about the railing of the platform, they would be the most warm and comfortable engines for the men of any upon either of the railways on which I have been. As it is, there is very little to complain of. With ample room, and nearly as much protection from the wind and weather as it is possible to afford, the men ought to be, and I believe are, very well satisfied.

From the great length, breadth, and weight of these engines, as I have before observed, they keep their legs; and I am not aware of any case in which, when thrown off the rails, they have upset. Like

sturdy giants, they maintain their feet, whatever foes oppose them. But, with all these good qualities, I cannot say I am an admirer of their motions. I have observed more rolling and pitching in these locomotives than in almost any engines on which I have traveled; and their lurches and plunges, if the engine is a little out of order, when going at a high speed, are almost awful. Nor am I alone in this opinion. Men to whom I have spoken, who have had experience with these and other engines, think of them as I do, and would prefer one of the tight little four-wheel engines to any of the Great Western.

Their vast weight, two or three and twenty tons, at high velocities, must occasion great wear and tear to themselves and the road; as some of the men quaintly expressed it, "they kill themselves by their weight." The injurious effects of this ponderous load of engine metal and timbering appeared to me to be very manifest from this fact, that every engine on which I rode, that had been out but a few months, exhibited great symptoms of wear and excessive strains. In some, the driving wheels were as much as half, or three-quarters, of an inch out of truth; in others, the framings appeared much strained and shaken; and all which had done much work, were very loose in the brasses. So very marked did these cripple qualities appear to me, that at first I thought they had not a good tight engine upon the line, and imagined, like the man with the short neck, they must have been born so. But, by close observation, I found that these groggy qualities were almost always in proportion to the work the engine had done, and that their engines which had been but recently out were as tight and right as other people's. I was therefore forced to the conclusion that the Great Western engines, either from their weight, or the breadth of the way, or perhaps both together, wore faster and more than they usually do upon other railways. By a reference to facts, I find this to be the case. On the Manchester and Leeds, with their very heavy gradients, the cost of repairs to the engines was 2.62d. per mile run to the end of June last; on the London and Birmingham, 4.17d.; and on the Great Western, 4.6d. In this comparison, it must be borne in mind that the Great Western has by far the best of it, in gradients and curves, of either of the other lines; and in respect of the London and Birmingham line, the advantage is also considerably on the side of the Great Western, in having been more recently opened, and, consequently, having newer engines to work with. Two or three years hence, things will be more on a par, and the amount of repairs will become more apparent. In confirmation of my opinion hereon, I make the following extract from a letter I have just received from a gentleman practically engaged with locomotives:—"I take great interest in your account of the Great Western—*I may be wrong*, but, from what I saw of the construction of some of their engines in Lancashire, some weeks since, *I think* they have *an awful day of reckoning for repairs to come.*"

Every thing on this line is upon an enlarged scale. Their gigantic engines are followed out by a superior size of the carriages. The Great Western first-class carriages are almost traveling houses, and,

in comparison with the carriages of other companies, seem to have been destined for a different race of mortals. This company have been as prodigal of room as many of the others have been niggardly. After having traveled much in a Great Western first-class, one feels by no means at ease within the contracted limits of other carriages. Many observations have I heard, in the course of my travels, of the superior capacity and comfort of the Great Western carriages over all others. So frequent has this been, that I thought, once or twice, whether this company ought not to be proceeded against as general defamers, not in word but in deed, of other companies' concerns. For it is a fact, that they have occasioned more grumbling and fault-finding on other lines, than all the blunders and accidents put together. "What little poking holes these carriages are," quoth one, "in comparison of the Great Western." "Aye," says another, "they do well upon that line. One can walk, stand, sit, or lie down as he pleases in a Great Western carriage." "There ought to be an Act of Parliament," rejoins a tall third, "to compel other Companies to make their carriages as comfortable and roomy as the Great Western. One has not room to put his legs here."

It is to be regretted that they have not maintained the same superiority in their second-class carriages. I say maintained, because it is a fact that the Great Western second-class carriages were originally really very comfortable vehicles, having closed up sides and glass doors, like the Grand Junction: but it seems they were too good for the first-class.

Though no one can help admiring the Great Western first-class carriages, it is a matter for consideration at what extra expense to the Company these comforts are purchased. I remember once to have measured the front area of one of these first-class carriages, and found it nearly 62 square feet, exclusive of the wheels. At 40 miles an hour, therefore, the resistance of the atmosphere increases the draft by at least 46 tons extra load upon the first carriage, and taking the whole train, probably by 50 per cent. more. It is therefore, as observed, worthy of consideration, whether this great comfort may not be purchased at too dear a rate. A few years' experience, as I have said before, will be the best proof.

Experiments have taken place during the whole period of the Great Western Railway, in one way or the other. Some were trying, when I was at Bristol, upon the making of coke, but with what result I have not heard. There has been a considerable saving in the price of coke, and some in the consumption of it in the locomotives. For instance, in 1840 the engines consumed 50 lbs. to the mile, at a cost of 38s. 6d. per ton; but in the present year they are only using 46 lbs. at 31s. 7d. per ton. The saving in the consumption has been by putting lap to the valves, and that very lately. With both things, that is, the lap and reduction of price, the saving has been in the ratio of 1,925 to 1,443, or pretty exactly 25 per cent.

Not long since I have heard that an experiment was tried upon this line of eighty miles run. The engine, with its coke and water, weighed 23 tons, the tender 14, the load of the carriages and their

cargo 70 tons, making a gross total of 107 tons, and the whole was taken at an average speed of 27 miles an hour, at a consumption of 45 lbs. of coke per mile. The load on the leading wheels of this engine weighed 7½ tons, on the driving 9½, and on the trailing wheels 6 tons, which is about the general proportion of distribution of weight in the Great Western engines.

Some experiments have also been tried with Craig's rotary engine, that is, an engine on the old, or Hiero's, principle, with a view to its application to locomotives; but, though I have an outline of an experiment thus made last summer, I have not heard that there is any chance of its being applied to locomotives.

The following is a comparison of a few of the parts of the Great Western engines with Bury's, Stephenson's old engines, and his last patent engine.

	Great Western 6 wheel.	Bury's 4 wheel.	Stephenson's 6 wheel eng's	
			New.	Old.
Diameter of cylinder,	14 & 15 in.	12 in.	14 in.	12 in.
Length of stroke,	18 in.	18 in.	20 in.	18 in.
Diam. of driving wheels,	6f. and 7f.	5½ feet.	5½ ft.	5 ft.
Distance between extreme axles,	13f. 2 in.	5¼ feet.	10 f. 8 in.	10 ft.
Distance of centres of cylinders,	3 ft.	1 f. 10½ in.	2 f. 4 in.	2 ft. 7 in.
Distance between bearings on driving wheels,	4f. 7in. inside, & 8f. 6 in. outside.	3 ft. 3 in. inside bearings.	3 f. 10 in. inside bearings.	6 ft. outside bearings.

Square Feet of Heating Surface.

	Great Western 4 wheel.	Midland Counties 4 wheel.
In fire-box,	97 feet	47
In tube surface,	699	441
Dimensions of posts,	11 × 1¼ wide	steam 6½ × exhaust 6½ × 2¼
Length of connecting rod,	5 feet	5¼
Diameter of leading wheels,	3½ and 4	4

This company have 107 engines, all six wheel. They are almost all built on the same pattern, and have 6 or 7 feet driving wheels. Their average weight, loaded, is about 22 or 23 tons, and 14 tons the tender, with its complement of coke and water. Of these engines, I was assured by three different persons, there were not more than 40, or, at the outside, 50, at any time, in an efficient state, and able to take a train. The consumption of coke is about 46 lbs. to the mile,

and the steam pressure which I observed in most was 55 lbs. to the inch. I believe, however, on some engines they work with a higher, and on others a lower, pressure; but 55 lbs. was what the valve was screwed down to in those I noticed, and I was informed it was the general pressure.

The following are the returns which I have received from the company. The number of engines is about 100, all six wheel, from 19 to 21 tons weight, loaded with water and coke. On the driving wheels the weight is from 8½ to 9 tons, and nearly balanced on the leading and trailing wheels, that is, about 5¼ or 5½ on each of the other pair. Of their engines, almost all are in a fit state to take a train. The play of the wheels on the rails is about ¾ inch; the pressure worked with 50 lbs. to the inch; the cost of the engines from £1800 to £2000; consumption of coke 31 lbs. per mile for passenger engines, and 40 lbs. for goods; and the total expense of locomotive power about 15d. per mile; but it has been more, and is decreasing. The distance between the centres of the cylinders is 2¼ feet, and the engines do not work expansively. Their engines have no particular kind of motion when the road is good. They have no top-heavy engines. Some of the goods engines are coupled, and work very well, and all the engines have flanches on the driving wheels. The gross average load of the passenger trains, including engines and tender, is 116 tons, and of goods from 300 to 400 tons.

The extreme length of the frame of the engines is 22 feet, and 13 feet to 13½ feet the distance of the extreme axles. The driving wheels are 6 feet and 7 feet diameter, but chiefly the latter; the other wheels are 3½ to four feet; cylinders, 14 to 16 inches diameter; and stroke 18 inches.

They have had very few detentions from derangement or failure of machinery, and only five or six broken axles, one from defective welding, the rest from bad iron. Two or three of these fractures have been in coupled engines. In all these cases they were unable to proceed with their trains, but no accident happened to any one. They have had no engines run off the rails.

(To be continued.)

A few Statistical Facts on the Revenue and Expenditure of the two most expensive long, and two moderately expensive Railways. *By* John Herapath, Esq.

At a time when so much is said upon the question of good and bad railways, and when traffic and expenditure are matters of warm discussion, I have thought a few calculations and observations on the recent reports may not be unacceptable. For the purpose I have in view, I have selected two of the most costly long lines, the Birmingham and Great Western, and two of those which are considered reasonable in their cost of construction, namely, the Grand Junction and South Western.

It will be seen that, in my comparisons, I have had labor which has not been lessened by the very dissimilar manner in which the

companies keep their accounts; but, if it will at all aid those to form sounder notions who are anxious to embark in railway property—for I can hardly expect it will be of much service to old railway stagers —I shall consider that my time has not been misspent.

I trust that my readers will distinctly bear in mind that my computations are based upon the data furnished by the last reports of the companies, for the genuineness of any of which data I do not hold myself answerable. If there has been any cooking in any of the accounts, the sin of it is none of mine. All that I hold myself accountable for is the calculations, which I have endeavored to make, and which I hope will be found, correct.

By the last half-yearly reports of the London and Birmingham, Grand Junction, South Western, and Great Western, Companies, the amounts called up in shares and loans, excluding shillings and pence, are—

	Lond. and Birm.	Grand Junction.	South Western.	Great Western.
Shares,	3,615,897	1,780,490	1,825,507	3,009,311
Loans,	2,278,654	483,362	630,100	3,332,025
Totals,	5,894,551	2,263,852	2,455,607	6,341,336

This is what I consider pure capital, disentangled from other items with which the accounts are encumbered. For instance, in the London and Birmingham account is a sum of £9,561 for "premium realized on the reserved new £32 shares," which, though put into the capital account, appears to me to be more of a contingency than, *bonâ fide*, a part of the capital. Again, in the Grand Junction, there is about the same sum made up of sale of refused shares, and of materials which, not having included at the time I made the calculations, though the sale of the refused shares forms certainly a very legitimate element of the capital, is not comprehended in the above statement. So £24,449, made up of "profit on shares," and "interest," carried to capital in the South Western, I have not called part of the capital, for the same reason as in the London and Birmingham, namely, that it appears to me to be a kind of accidental windfall, rather than legitimate capital. The same might be said of about £3000 in the Great Western account, for "registration fees" and "rents." This company is the only one of the four which does not exhibit a capital account, but gives simply a balance sheet of receipts and expenditure, including the half year's traffic and expenses. In the South Western, £296,545 belonging to the Gosport Branch is at present tantamount to a loan, having only 5 per cent. interest now paid on it. In August next it will be converted into shares, and receive a dividend. At present, however, it diminishes the share capital, and augments the debt, of the company, from 27.15 per cent. to 60.60, as in the following summary:

Thus, for every £100 of actual capital raised by shares, the

London and Birmingham	have severally	£63.03
Grand Junction		27.15
South Western		34·52 or 60 60
Great Western		110.72

of borrowed money taken up either on mortgage or loan notes. It appears, therefore, that an amount of debt nearly equal to two-thirds of the entire property of the shareholders stands against the London and Birmingham Railway; and a debt of something more than a fourth of their property against the shareholders of the Grand Junction; and in the South Western, of above a third; while in the Great Western the debt exceeds, by nearly eleven per cent., the whole property the shareholders have in the concern. It is not for us to say whether the legislature did, or did not, contemplate such very large debts as are here contracted. Fortunate, however, it certainly is, that in the first, and particularly the last, of these lines, that their per cent. profit upon the whole capital and debt together, exceeds that of their debt; for, were it otherwise, the shareholders would be in a most melancholy position. As it is, it is a great advantage to them to be in debt, and we should recommend them to keep so as much and as long as they can.

The Grand Junction have, by a little dexterity, reduced their capital to only £2,203,300. For, finding their shares at a high premium, they very adroitly hit on an expedient of paying off their debt at a considerable saving to the company, and, at the same time, with great benefit to the shareholders. For instance, they created 17,624 quarter shares, representing in capital only £440,600, and they say to the receivers of these, "Now, if you will take upon yourselves to pay the interest of the debt, and the debt itself, as it falls in, we will give you the full dividend upon these quarter shares, and, when you shall have paid off the debt, we shall save in capital near £100,000." As yet, only 2*l.* 10*s.*, or £44,060, have been called up, and these quarter shareholders stand in this position:—they are receiving at the rate of 3*l.* per annum on the 2*l.* 10*s.* paid up, out of which they have to pay 1*l.* 2*s.* 6*d.* per annum, for interest, leaving 1*l.* 7*s.* 6*d.* net for their clear dividend on their 2*l.* 10*s.* share, or about 54 per cent. But, as a set off, they have still to pay about 27*l.* 8*s.* 6*d.* on each of these quarter shares, besides the already paid sum of 2*l.* 10*s.*; that is, the quarter shares will cost somewhere about 30*l.* each.

In the same way, the London and Birmingham Company are paying the full dividend on their quarter shares, on which only 5*l.* has been paid. I have never, however, heard with what prospective advantage to the company this was done. The Grand Junction plan is a good contrivance eventually for saving capital to the company, though at present at the expense of the other shares; but the London and Birmingham plan appears to me to be now damaging the original holders, and with no prospective benefit.

Supposing D to be the per cent. amount of debt on the capital actually paid, or the per cent. interest on it, *i* the per cent. interest on the capital and debts together which the profits would pay, and *s* the per cent. dividend on the shares or capital alone after paying the interest, we have the following simple equation from which to deduce any one from the rest, namely:—

$$100\,s + D\,d = (100 + D)\,i.$$

$$\text{Whence } s = i + \frac{i - d}{100} D \text{ and } i = \frac{100\,s + D\,d}{100 + D}$$

By the second equation it appears that if the debt was about one-fourth of the paid-up capital, and the interest of the debt was 5 per cent., and the concern paid 11¾ per cent., the shareholders ought to divide nearly 13½ per cent. This, as we shall presently see, is the case with the Grand Junction, considering their loan as a debt; but they have only divided 12, in consequence, chiefly, of the heavy sum they have laid by for depreciation and a reserved fund, and the operation of the quarter shares.

If we were to go closer into details, they ought to have a better dividend than we have given them, because we have not taken in the whole of their half-year's income, nor £9000 balance on the preceding account, while we have comprehended every item of their expenditure for the half-year, and have only reckoned the debt 25 per cent., whereas it exceeds 27.

If the debt was two-thirds of the paid-up capital and interest together, and the profits would return 10 per cent. on the whole debt and capital, the shares, with 5 per cent. interest on the loans, might divide near 13⅓ per cent. on the paid-up capital. This is nearly the position of the London and Birmingham Company. Owing, however, to the large sum set apart for depreciation and the quarter shares, on which, as I have said, only 5*l.* capital is paid up, receiving the full dividend as if 25*l.* had been paid, the old shares only receive 9¼*l.* per share, or about 10½ per cent. Such is the unfortunate operation of these preference shares and the depreciation fund. It is true we have reckoned the debt larger, and, therefore, more advantageous than it is to the shareholders, and have taken the interest divisible upon the total cost greater than it really is; but after making due allowances for all this, the dividend on the shares would cover 13 per cent., if it was not for the operation of the preference shares and the depreciation fund.

With the South Western they only pay 5 per cent. interest on the Gosport branch, that is, on an additional £296,500, which reduces their paid-up capital to £1,529,000, and increases their debts to £926,600, or to above 60 per cent. of it. On the total of capital and loan, we shall find presently that this company can pay 6¾ per cent. Therefore, allowing 5 per cent. upon the debt, which is $\frac{3}{7}$ths of the paid-up capital, and we shall have 7.80 for the dividend per cent., which might be made on the shares. The amount divided is near 7¾ per cent., very nearly the full one, and they hold a balance of £8750 in hand.

The Great Western would pay 5.8 per cent. on the loans and capital, and has 110.7 per cent. of paid capital in loans. Therefore, if 5 per cent. be paid on these, the dividend ought to be 6.7 per cent. on the shares. At the last meeting, a dividend of 6 per cent. was declared.

The length of line run by the London and Birmingham, including the Aylesbury branch, is 119¼ miles; of the Grand Junction, including the Liverpool and Manchester, and Chester and Crewe, it is about 133½; of the South Western, taking in the Gosport branch, 92¾; and of the Great Western, including the Bristol and Exeter, and Cheltenham Union, 169 miles. Hence, taking the receipts earned during the past half-year, exclusive of other sources of revenue, and the expenditures, we have—

	Length work'd miles.	Half-year's Receipts.	Half-year's Expend.	Receipts per mile.	Expend. per mile.	Per centage of expen. on receipts.	P. ct. on cap. and loans for ½ year of Receipts	Expen.	½ yr's profit per cent. on Capital and loans.	Paid up cap. alone	Cost per mile.
		£	£	£	£	£	£	£	£	£	£
L.&B.	119¼	429023	134684	3590.2	1132.3	31·68 5	7·2782	2·3061	4.9721	6.53	52396
Gr. J.	133½	238207	104988	1784.2	784.6	43.9 73	10.5220	4·6375	5.8845	6.80	21525*
S. W.	92¾	153162	70284	1651.3	757.8	45.889	6.2372	2·8622	3.3750	3.91	26475
G. W.	169	337008	152787	1994.2	904.1	45.336	5.3145	2·4094	2.9051	3.35	53968

* This is given by Mr. Moss, the Chairman. The other costs per mile are computed upon the number of miles constructed.

This table affords us some very instructive information.

Many persons, for example, imagine that the amount of traffic per mile per week, as given in the Railway Magazine at the request of some high authorities, is indicative of the value of the line. Taking an extreme case, this would be true, for if a line had no traffic at all, it evidently could be of no value. But the gross amount of traffic, or the amount per mile, goes a very little way towards deciding the merits of a line. For instance, we have here the London and Birmingham at the head of all the railways in receipts, and more than double of another railway, the Grand Junction, which divides upon its whole cost, and with the dead weight of the Chester and Crewe hanging upon it, near 2 per cent. more. Receipts, therefore, are poor criteria of the merits of a line. They are good tests of the quantity of business done, and of the foundation on which profits may be made, but go no further.

Others, again, think the expense per mile a proof of the economy or extravagance of a company in the management of their affairs. This is a position equally as absurd as the preceding. The London and Birmingham is, upon this principle, nearly twice as extravagant as the South Western, and yet it would pay, upon the whole cost, near 3 per cent. per annum more dividend. Again, the Grand Junction is, if expenses per mile are a test, less economical than the South Western; nevertheless, it pays a good way towards double the dividend. A little reflection would tell us that the mileage expenses are influenced more by the amount of business done, than by the economy

of management. But there are some, and even public writers, who have such crude notions upon railways, as to make high mileage expenses a ground of complaint against companies.

Equally absurd is another point on which much stress has been laid. I allude to the expenses per cent. of the traffic upon the receipts. Many persons exclaim, if one company transacts their business at a higher per centage than others, that things are worse managed there than where the per centage expense is much less. Referring to our table again, and we shall perceive the unsoundness of this doctrine. The Grand Junction is near 40 per cent., on the per centage expenses, more expensive than the London and Birmingham, and nevertheless can divide upon its whole cost at the rate of 11¾ per cent., while the London and Birmingham cannot divide 10. Again, the South Western is apparently paying a higher per centage expense on its receipts than the Great Western, and the receipts per mile are much less; and yet it pays at the rate of 6¾ per cent. on its cost, while the Great Western cannot pay at the rate of 6 on its cost, though it has divided, and apparently justifiably, at the rate of 6 on the paid-up capital.

The fact is, the per centage expenses depend upon two things, the fares and the amount of business. Other things alike, if the fares are higher, the per centage expenses will be less, and *vice versa*. Again, the more business, the less in proportion is the expense at which it can be done, simply because the standing expenses will bear a less proportion to the receipts, when great, than they will when little. For my part, I would rather see, where there is a scope for business, the per cent. expenses high, for the probability is there would be much more trade and profit.

The fact is, receipts or expenses per mile, or per centage expenses on receipts, are all fallacious foundations upon which, separately, to ground an opinion in favor of any line. *Railways are strictly commercial enterprises, and it is the annual per centage of profit alone on the capital, as in any other undertaking, that determines its value.* The smaller, therefore, this capital is, the more likely the line is to pay, and hence every effort should be made, in the construction of the line, to keep the cost down. Had the London and Birmingham, with its immense trade, (nearly double that of either of the other lines,) been made at anything like its original estimate, or like the cost of either the Grand Junction or South Western, it would, with its economy of working, have paid a magnificent dividend. The same, no doubt, would be the case with the Great Western, when it comes into its full receipts, which will not probably be for these two or three years. Never was economy of construction more forcibly exemplified than in the comparison of the London and Birmingham and the Grand Junction. With more than a double business, and an expenditure proportionably much less, the Grand Junction leaves the London and Birmingham far in the rear of profitable undertakings, for no other reason than that the total mileage cost of construction of the one has been about 143 per cent. more than that of the other. But the Grand Junction, nearly the lowest of the four in the amount

of its business, having been constructed the cheapest, stands at the head of them all as a commercial speculation. Railway Mag.

Observations upon the Comparative Advantages and Inconveniences of the Employment of Iron Wire, or Bar Iron, in the Construction of Suspension Bridges of great span. By M. Le Blanc, *Chief Engineer of Bridges and Roads.*

Cables of iron wire, and chains composed of bars of wrought iron, may be compared with reference to their economy and their durability. As regards economy, the question scarcely deserves discussion, and it is easy to prove *à priori* that, in all possible cases, iron wire has the advantage over wrought iron. In fact, the Council of the Ponts et Chaussèes has adopted the principle, that cables of iron wire should be submitted to a tension of 12 kilogrammes (26½ lbs.) per square millimetre (.0016 square inches) of section; but for bar iron it was decided that the *maximum* of tension shall not exceed 8 kilogrammes (17.6 lbs. nearly). This principle is founded upon the comparative resistance of iron wire, No. 18, ordinarily employed in the construction of cables, and of iron bars 3 to 6 centimetres (1.2 to 2.4 inches) in diameter.

The natural consequence of this principle is, that the section of a chain should be greater by one-half than that of a cable, for the same tension; this involves a proportional increase of its weight. In cables of iron wire no joints are used, or, at most, but a single one, as in the bridge of Argentat; and this joint, made up of two small eyes, weighs but little—on the contrary, they are numerous in chains, and, where the system is rather complicated, as I shall prove it should be in bridges of great span, each one of these joints weighs at least 140 kilogrammes, (300 lbs.) On the supposition that the suspension rods are 1.2 metre apart, (47¼ inches,) as there is a joint for each rod, there will be 233 kilogrammes (514 lbs. nearly) for a bridge of 180 metres (590 feet) span. This additional weight, together with that of the bars themselves, which, as we have just seen, is one-half greater than that of the cables, produces an excess of tension which must again be resisted, whence there arises a new increase of section, and, consequently, of weight, in the chains. In applying these principles to individual cases, it is found that the weight of the unit of length of a system of chains exceeds double that of a system of cables.[1] Now, as the price of iron wire is once and a half that of bar iron, it is plain that the use of iron wire is more economical than that of wrought-iron.

I have proved that the total tension is much greater when chains are used; it follows that greater strength must be given to the moorings, and to the intermediate piers, when the bridges have several openings, or bays—a new cause of increase of expense.[2] It appears

1 In the comparative proposals which I presented for the bridge of Roche Bernard, I showed that these weights are in the proportion of 11 to 25; in order to replace 11 kilogrammes (24 lbs.) of iron wire, which, at 1f. 50c., cost 16f. 50c., we must employ 25 kilogrammes (55 lbs.) of wrought iron with 25 francs.

2 In bridges of several bays, the cables, or chains, should be fixed to the intermediate

to us to have been thus thoroughly proved, that, in regard to economy, the cables of iron wire are superior to chains of wrought-iron. Let us now compare the two systems in relation to their durability. The principal objections which have been made to the employment of iron wires are the following:

1st. They offer greater chances for rapid oxidation.

2d. The imperfection of the present process for manufacturing the cables, does not allow us to give an equal tension to all the wires, so that, when the cables are raised to their places, the wires which are under most tension have to support many pounds in excess—while those under least tension do not draw at all.

3d. Cables form a system less rigid than chains of wrought-iron do, so that the horizontal oscillations of the roadway are more considerable in the former than in the latter case.

I believe that I have not withheld any of the objections urged against the employment of iron wire, nor weakened those I have presented. I shall now examine them in order.

First objection.—They offer a much greater chance for oxidation.

It is certain that if we expose to alternation of dryness and humidity a bar of iron and a certain number of isolated wires, the sum total of their individual sections being equal to that of the bar, the surface attacked will be far greater in the wires, and in them the oxidation will be most rapid.

In confining ourselves to this general fact, without reference to any of the means employed by art for retarding this oxidation, it will be well to examine if even this inconvenience of the more rapid destruction of the cables is not more than counterbalanced by the advantages which they present. It is very evident that if the cables remain only forty years without being renewed, while the chains may last for sixty or one hundred years, we must calculate what will be the amount, at the end of forty years, of the sum saved by the use of iron wire instead of bar iron.

To render this more plain, I will give an example. I suppose that a given suspension bridge requires 200,000 kilogrammes (441,096 lbs.) of iron, (which was nearly the quantity for the bridge of Roche Bernard.)

The expense of the system of suspensions,	300,000 francs.
According to note, (1,) to replace the iron wire, there must be used 454,545 kilogrammes of wrought-iron, which would cost	454,545 "
Saving in favor of iron wire,	154,545 francs.

piers, in order to avoid the great changes of form which result from unequal loads upon the two bays, if the chains and cables can slide freely over the top of the piers, because these piers have to resist only the difference of the tractions produced by different additional loads upon the two bays, it would appear, at first sight, a matter of indifference whether the permanent loads which are in equilibrio are greater or less; nevertheless, it is plain that, the less these permanent loads are, the better the piers are in condition to resist the *maximum* load of one bay, the other being destroyed—it is, then, not unimportant that we diminish the permanent load as much as possible.

Now, this sum, put at interest, will amount, at the end of twenty-three years, to 475,506 francs; and, supposing that the cables must be entirely renewed at this time, there will still remain a surplus of 175,596 francs, which will be more than sufficient to produce, at the end of another twenty-three years, a new capital equal to the cost of the system of suspension. In the case which we have considered, cables of iron wire, lasting but twenty-three years, will then be preferable to chains of indefinite duration. The supposition that isolated wires will last twenty-three years without the necessity of being renewed, is not without foundation, and we shall produce a fact which strongly tends to confirm it.

M. Montgolfier, Jr., having learned that a grating of iron wire from the church of St. Martin's, at Paris, was about being taken down, after having remained forty years without any repair, had the curiosity to prove these wires, after having carefully ascertained their number, and he was convinced that they had lost but one-fifth of their entire strength.* This loss of strength is not sufficient to require a complete renewal of the system of cables. But the most determined opponents of the use of iron wire confess that cables do not afford such facilities for oxidation as detached wires. The greasy substance which covers them affords a powerful preventive to rust—their union preserves them in the interior, more or less, from moist air—the ligatures are a still further obstacle to its introduction—and, finally, the careful superintendence which should be given, are all reasonable motives for hoping that the effects of oxidation may be diminished in a remarkable manner.

It may be objected that experience has not fully confirmed the opinion, however probable it may be, that cables are less susceptible of the attacks of oxidation than iron wires. I confess that no one fact can, as yet, incontestibly, prove the justice of this opinion; but there are several which we can produce, capable of giving much strength to it.

The bridge of Tournon has been in existence eleven years, but no very considerable trace of oxidation has manifested itself, at least to my observation, upon the surface of the cables; and, if there existed any in the interior, it would not have failed to show itself by a brownish stain upon the outside of the paint which covers them.

A bridge of iron wire was built at Brest in 1526; the cables, exposed to the salt air, which attacks iron with so much energy, should have undergone a remarkable deterioration in the space of three years. M. Trotte de la Roche, Chief Engineer, who, on account of the plans adopted for the port, was obliged to dismount it, took the pains, at the invitation of M. Inspector General Lamblardie, to prepare a *proces verbal* of the state in which he found the cables.

It appears from the *proces verbal*, 1st. That the continuous ligature which covered the cables was slightly attacked, but that by the first scratch of the file the oxidized portion was removed. 2d. That the

* The increase of oxidation is not as rapid as would be supposed from the first observations made—for the first layer of rust which covers the surface of a bar of iron, instead of favoring this oxidation, proves a coating which is an obstacle to it.

exterior wires of the cables showed slight traces of oxidation, but that the slightest scratch of the file caused them to disappear. (M. Trotte de la Roche supposes that the oxide was only deposited upon the wires of the cables, and that it came from the ligatures.) 3d. That the interior wires were perfectly untouched. Eight years is a short space of time, but if we consider that the effects of oxidation probably continue to decrease, we may conclude that they are not so very rapid, but that the fears entertained upon this point are greatly exaggerated. An observation has been made which is worthy of remark; it is, that, in chains, the surface of the bars, which is attacked by oxidation, proves the portion of them offering the most resistance, while, in a cable, the interior portions have the same strength with the others.

Second objection.—The imperfection of the present process for manufacturing the cables, does not allow of an equal tension in all of the wires, so that, when the cable is raised to its place, the wires under most tension are overstrained by many pounds, while those under the least tension do not draw at all.

This last objection is a serious one, and cannot be absolutely done away with—that is to say, it is impossible to prove that this defect does not deserve the most serious attention; but we can employ, in defence of iron wire, negative arguments, or, in other words, we can prove that it is not possible to resolve the problem of equal tension in a more perfect manner by the system of chains than by that of cables of iron wire. We must, in the first place, distinguish carefully between bridges of large or small span; in the latter, where the tension requires only a section of the chains equal to that of 4 to 8 bars of about 0.05 metres to 0.06 metres (2 to 2½ in.) in diameter,* (dimensions beyond which the quality of the iron becomes considerably deteriorated,) we can establish, on each side of the bridge, two or four separate chains, in one or two layers, each chain being made of a single bar only; in these two cases the problem of equal tension is perfectly resolved, and although, in the second, each suspension rod bears upon two chains which cannot have exactly the same curvature, the holding plate of the rods will always bear upon the two chains, which will then support equally their share of the whole weight of the bridge. By establishing three, or even four, layers,† we can form an excellent system of sixteen chains, each made of a single bar; but these sixteen chains present only a total section of less than 44,000 millimetres, (97,041 lbs.) corresponding to a tension of 352,000 kilogrammes, (776,329 lbs.)—that is to say, to bridges of medium span; but if we pass to bridges of such a span that the tension increases to more than a million of kilogrammes, it will be necessary that the chains should be composed of 48, or even 64, bars—that is, 24, or even 32, bars on each side.

Let us consider the last hypothesis, which applies to the case of the

* I reason on the supposition of the use of round iron, of which I need not prove the superiority over square iron, that is hammered again after being reheated to a cherry red.

† I suppose it would not be desirable to employ more than four layers—this number is already considerable and troublesome in the passage over the towers, and in the moorings.

bridge of Roche Bernard. It is impossible to employ the simple system of suspension rods resting upon a couple of chains, of single bars, and arranged in layers, for we would then have sixteen of these layers, one above the other, which, beside the inconvenience presented by a considerable height, would allow of the attachment of suspension rods only at every sixteen intervals upon the same chain. Here, then, it is necessary to employ a more complicated system, viz., to form the chains of several bars, fastened together by a single bolt; in this case, I would reduce the number of chains to eight, and form them of eight bars, fastened by one bolt. We can double the number of chains, and so reduce to four the bars in each, by making each rod rest, by means of plates, upon two chains at once; but if the two chains forming the couple are not in the same plane, the upper plate of the rods will bear only upon one of the chains—for it must remain parallel to the plane of the four bars—and one-half of the system will support nothing; this disposition is too faulty to be adopted—this is my opinion in the hypothesis of eight bars to each chain, and fastened by one bolt.

Whatever may be the manner of forming the eye at the end of the bar, either by welding it to the end itself, or by bending over a portion of the bar, it appears to me very difficult to prevent differences in length of at least a millimetre between the bars. Now, if there is this difference between bars, 5 metres (16.4 feet) in length, the shortest must lengthen a millimetre, or .0002 of their length, before the others draw. But we know that a tension of two kilogrammes per square millimetre of section produces, upon a bar, an elongation of .0002 of its length. The bars, then, of which we are now speaking, are strained to the amount of 4 kilogrammes (9 lbs.) per square millimetre, before those beside them suffer any tension; what will this amount to if the differences in length are more than one millimetre?

We see, then, that the problem of equal tension is as difficult of resolution for a complicated system of chains as for iron cables; for, supposing that, in the two systems, the excess of tension, either of one wire over another, or of one bar over another, is the same, this excess will be a much smaller fraction of the absolute strength of wire than of bar iron; moreover, the manufacture of cables affords a greater hope of perfection than that of chains.* We see, now, that the second objection has no more weight than the first, to decide us in favor of wrought iron chains.

On the other hand, there are objections against the employment of bar iron more difficult to remove, and which will give additional strength to the reasons which have induced me to yield the preference to iron cables. These objections are as follow:

1st. The greater part of chain bridges which have fallen have given way at the bolts which unite the links. Now, it is extremely difficult

* To make the bars as equal as possible, we can, indeed, after having bent and welded the ends, drill through all of them which make up a link of the chain, when cold; but it is evident in this case, that, to prevent the drilling from diminishing the strength of the eye, we must either give greater size to the bar in this part, or flatten it, involving a heating which injures the quality of the iron.

to calculate the strength which should be given to them, as we do not perfectly understand the manner in which they resist the strain; if we compare them to bars placed upon fixed bearing points, and charged with a weight in the middle, and the resistance of which is derived from a formula $P = M\frac{a\,b^2}{2\,c}$, we find the dimensions very small—too small, indeed, according to many experiments. If we suppose them to resist, as if drawn in the direction of their length, (and many constructors admit this hypothesis,) we arrive at large sections, which greatly increase the weight of the joint; besides this, we have no certain information as to the quality of the iron which they need; it should not be so soft as that of the chains, because no curvature is required, but still it should not be brittle. To avoid mistakes prejudicial to the durability of the work, it is wise to make them rather too strong than too weak; but, as I have just said, an increase of weight is the consequence of this precaution.

2d. The making of the eye requires great attention; it has been observed, that, when the bolt is too little, during the proof, a rent takes place from the outside to the inside of the head of the eye; when the bolt is too large, the rent opens from the inside toward the outside. Now, as it is almost impossible that the work of man should be perfect, in order to avoid the inconvenience abovementioned, several constructors have proposed to swell out the head of the eye, in order to give it greater strength; but, to do this, we must re-disturb the particles of iron, by hammering after having heated it—an operation which I have already designated as faulty.

3d. During the oscillatory motions, which take place in all suspension bridges, the irons rub forcibly against each other at all the joints, and this tends to wear them in those parts which have the greatest strain. This inconvenience does not exist in wire cables.

4th. In the moorings we are compelled to use curved irons, which have, of course, been re-heated,* and are most often squared; this new heating, and the difficulty of proving them, obliges us to give a greater size, which involves another increase of expense.

5th. In very cold weather, iron becomes brittle; wire, enveloped in grease, and not in immediate contact with the air, must be less brittle than naked bars of iron.

6th. Cables, in bridges of great span, can be much more easily raised to their places than chains. In the proposal for the bridge of Roche Bernard, I have calculated that the weight of a cable would be 7968 kilogrammes, (17,673 lbs.,) while each chain would weigh 31,496, (69,462 lbs.) A work equally difficult, it may be said, has been executed at the Menai bridge; but if this proves that it is not impossible, it does not prove that it is not very difficult.

* There are, for instance, some red shear (hot short) irons which lose nothing by being wrought at a white heat, but which are injured in quality when wrought at a less elevated temperature. But the workmen cannot confine themselves to fulfil those conditions exactly, whence it happens, in irons which have even been proved, that the reforged portions become bad, and, consequently, that only the final proof can give evidence of this imperfection; but, as we have just said, it is very difficult to prove curved bars.

M. Vicat has asserted that wires, before breaking, suffer a considerable elongation, which announces the rupture beforehand, and thus gives time to make the necessary repairs, while chains break instantaneously. This advantage of iron wire has been disputed, in the case of wires united in bundles by ligatures, and the interstices of which are filled by grease. M. Frinot thinks that these bundles form a brittle system; he, doubtless, would like to say, as brittle as bar iron. In support of his opinion he has cited the "herse," a sort of skein of hempen thread, which has most strength when its elements are free, and loses part of it as soon as the loose threads are bound together, and approximated to the condition of ropes. If this assertion is confirmed by experiments—and I have prepared some for this purpose—cables will, in this point of view, be neither worse nor better than bar iron.

Third objection.—Cables form a less rigid system than bars of wrought iron, so that the horizontal vibrations of the roadway are much greater in the former than in the latter. For equal curves and weights, this is true; but when we have once given the preference, even in point of durability, to wire over bar iron, (and I confess I have done so,) will we not gain more by increasing the rigidity, by means of the greater weight of heavier timbers for the roadway, and by diminishing the curvature of the cables, or the tension which they should bear per square millimetre of section, than by substituting chains for cables? These latter likewise admit of an arrangement which cannot be adopted for chains. I refer to the cradle form; and, in this case, the outside cables being in a plane, inclined from the vertical, have a tendency to draw the whole roadway towards them, and, as this takes place on both sides, it follows that the roadway is kept in its position better than it would be by means of stays.

I offer these reflections to the readers of the Annales, as the result of perfect conviction in my own mind, after deliberate consideration; and I can indulge the hope that this conviction will be shared by at least a small number of my associates. I shall examine, in a subsequent article, the advantages and inconveniences of a diminution of curvature, and the defects in the proof which chains and cables undergo, either before or after being placed.—*Annales des Mines.*

Mining Journal.

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

Explosion of the Boiler of the Steamboat Medora.

To the Committee on Publications.

GENTLEMEN—In my memoir of the explosion of the steamboat "Medora," published in the November number of the Journal, for 1842, I state (pages 320–21) that "another witness says, that, when the weights were pushed out by him on the long lever as far as they would go, the steam pressure was twenty-two inches by the gauge, having shown twenty inches just before, and that, by order of the

acting engine-man, he then put an *additional* weight, (how much he does not say,) and that, two or three minutes afterwards, the boiler blew up." The witness here referred to was Mr. Joseph Cragg, who, though not mentioned by name in my memoir, has been so connected, by the newspaper accounts of the accident, with the treatment of the safety valve just before the explosion, that, in the belief that he would be recognized by the readers of the Journal, and be visited with their censure, he has recently called upon me to request that I would cause his explanatory statement, which follows, to appear in the Journal, as an appendix to the history of the occurrence it contains. I comply cheerfully with Mr. Cragg's request, which indicates a proper anxiety to free himself from the imputation of a want of due regard for his own life and those of others. I also add the statements of Messrs. Ramsay and Collins, who accompanied Mr. Cragg in his interview with me, and who were with him in the Medora when she blew up. I had seen none of these individuals at the time of preparing my memoir, and I have, since submitting it, regretted that my leisure did not allow me to make more extensive inquiries, into the circumstances of the explosion, among its surviving eye-witnesses. Many of these (and among them the three just mentioned) were indeed, at the time of my examination of the matter, not in a condition to be seen and questioned respecting it; and I was therefore compelled to rely principally upon the evidence of those who, being more distant from the immediate scene of the explosion, escaped injury from it, but who, on that very account, were less correctly informed of its attendant circumstances. The official inquisition into the affair, though promptly instituted, and commendably attended to by the Mayor in person, led, as usual in such investigations in this country, to no determinate results. We could learn useful lessons from the old world in the conduct of these inquiries, which should always be of the most searching kind, and be prosecuted with the utmost rigor by the local tribunals, which ought to be vested with all the powers necessary to that object.

Mr. Cragg says that, shortly before the explosion, he was standing near the boiler, and, observing the steam *weeping* out of the safety valve, he mentioned the fact to Duncan Ferguson, the engineer, who requested him to push the weight out upon the lever. He (Cragg) accordingly took down, and set upon the deck, a door in the house surrounding the boiler, which door was immediately opposite the lever, and, when removed, gave access to it, and exposed it fully to view. Mr. Collins, who was standing by, held the door upright on the deck, while Cragg pushed out the *smaller* weight, (described in my memoir as weighing 56 lbs.) as far as it would go; that is, close

up against the larger weight of 200 lbs., already out at the extremity of the lever. The smaller weight laid, and was fitted upon, the lever by an open slot, or groove, in the bottom of the weight, which allowed it to slide to and fro. The opening in the larger weight which received the lever was, on the other hand, a longitudinal perforation through the centre of the weight, so that it could not (as could the smaller one) be dropped down upon the lever, but was pushed upon it from the end. The reason of this difference in the manner of supporting the two weights upon the lever, will be explained by Mr. Ramsay's testimony. Now, Mr. Cragg declares that the *additional weight* spoken of in my memoir was *this very smaller weight of* 56 *lbs., and that no other than the two weights therein described were put upon the lever; nor any other means, whatever, of holding it down, employed.* He further says, that as, *before* he pushed out the smaller weight, the steam was just beginning to escape from the safety valve, which was *dancing* on its seat; so, *after* that weight was slid out against the large one, the valve closed, so as to allow only two small puffs of steam to escape from them, up to the moment of the explosion. That after he had pushed out the weight, he went round to the gauge-cocks, and tried the two uppermost of the four, from the highest of which steam and water, and from the next lower water alone, issued. That he returned towards the safety valves, and was wiping his hands of the color he had got upon them from the newly painted door abovementioned, when the boiler exploded, and blew him out of the side of the boat, into the water. He barely escaped drowning; his face and leg were badly scalded; five of his ribs were broken; his sight was lost for a time, and he was confined for several weeks to his bed. He moreover says that the gauge stick, which a witness (one *Smith*, see p. 320,) states that he saw run up to the upper deck just before the explosion, *could not have been seen to do so*, on account of a board partition near to the gauge, *behind* which the stick would have passed up, so as to conceal it from view, for a space of some eighteen inches, before it could have reached the deck.

Mr. Cragg also states, that Mr. Watchman told him, some time after the accident, that, in speaking before the coroner's inquest of *extra weight* put upon the lever, he *meant* the 56 lbs., which has been spoken of all along as the smaller one of the weights *belonging to the valve*, and that he had no intention to find fault with what had been done by Mr. Cragg. The newspaper report of Mr. Watchman's examination before that inquest, leads, however, to a very different inference on the part of the reader of the report, who cannot help seeing that Mr. W., therein, intimated very plainly his belief that the extra weight of which he spoke had nothing, by right, to do with the valve,

but was specially provided for the occasion by those whom he supposed to have tampered with it.

Mr. Albert G. Ramsay, now the engineer of the steamboat Jewess, and who was to have been engineer of the Medora, stated to me that he was standing on the upper deck, close to the cylinder, when the boiler burst, and that, in attempting to get out of the way, he fell down into the hold, and nearly lost his life. He says that, in the two trials of the Medora previous to the day of the accident, the steam gauge was not in a situation to show the pressure correctly, because the *stick* was four or five inches too long, and because there was a considerable quantity of water, from condensed steam, in the vent tube, which water *floated* the stick; and also because the gauge board, with its accurate divisions, was not then up, but the inches merely marked with chalk on the bulkhead, from rough measurements, which he made himself; and that these measurements did not go above 24 inches, leaving all above that limit to be guessed at; so that he thinks the gauge, on those previous trials, showed perhaps nine or ten inches too much pressure. This, he thinks, may account for Mr. Watchman's having supposed (see memoir, p. 319,) that the boiler, on those occasions, had been proved to 27 and 31 inches of steam; while, in fact, the proof was perhaps to not more than 18 or 22 inches. That on the day of the explosion, however, an accurately marked scale had been put up, the stick reduced to its proper length, and the water removed from the mercury; so that the true pressure was shown on that occasion. Mr. Ramsay now further says, that, in the two preliminary trials of the boiler, the *only weight upon the lever was the large one*, of 200 lbs., which, of itself, could not have produced a steam pressure of more than 18 or 19 inches; and that the smaller weight of 56 lbs. was then cast and put upon the lever in the manner above described, to assist the deficient action of the large one, and that it was, on this account, considered and called an *extra weight*. He also says, that the space within which the small weight could be pushed backwards and forwards, when the large one was at the end of the lever, did not exceed nine inches, owing to an upright iron guide, which embraced and steadied the lever, at a distance of thirty-one inches back from its extremity. He states, furthermore, that the end of the lever came close up to, or rather *just through*, the boarding of the boiler-house; so that there was no room upon it to hang weights outside of the large one, and any such weights must have been seen, had they been so suspended.

Mr. Collins confirms Mr. Cragg's statement of the circumstances under which he pushed out the small weight upon the lever; and he (Collins) also affirms positively, that no other weights than the two

abovementioned were put upon the lever, which he had in full view through the open door of the boiler-house, up to almost the moment of the explosion, by which he was blown into the water, scalded, and otherwise injured.

Such is the testimony of the three individuals above named, which I respectfully ask may be published in the Journal, at their request, and *upon their accountability for its truth.* If its truth be admitted, it would appear that the steam pressure did not, in fact, rise above the amount ($23\frac{6}{10}$ lbs. per square inch) estimated in my memoir, and that the boiler gave way under that strain, although its strength was therein estimated to be $69\frac{44}{100}$ lbs. per square inch, or three times as great. We would then have to suppose the data on which the strength was computed to have been erroneous; that is, the iron must have been much weaker, or the workmanship less perfect, or the quantity of metal resisting the strain much smaller, than has been assumed in that computation. One or all of these possible errors in the elements of my calculations, may exist; but as I neglected no means of information available to me, I cannot blame myself if they are incorrect. The evidence is conflicting and unsatisfactory, and leaves the causes of the catastrophe involved in considerable uncertainty.

It appears that the three holes, *b*, *b*, *b*, shown in the back view of the boiler, were not *blown*, but *torn out*, having been the points of insertion of pumps, which were fastened down to the kelsons of the boat, and remained so attached when the boiler rose. This circumstance will assist in accounting for its rotation, previous to its fall.

I am, most respectfully, your ob't serv't,

BENJ. H. LATROBE, C. E.

Baltimore, Jan. 25, 1843.

Franklin Institute.

Report on the Carcel, or Mechanical, Lamp.

The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, to whom was referred for examination, by Mr. Alfred Bennett, the Carcel, or Mechanical Lamp, REPORT:

That the lamp is that long known in France as the Carcel Lamp, from the name of its inventor, and for several years in use in this city under the names, Diacon Lamp, and Mechanical Lamp.

In these lamps, the oil is raised to the wick by machinery contained within the ball, or stand. As no novelty is claimed by Mr. Bennett, the committee do not propose to describe this machinery, but proceed at once to the comparison of the light and expense of these lamps, with those of other lights in common use.

The comparison was made by means of a photometer, similar to that used by a former committee when examining Mr. Greenough's lamp and chemical oil. It consists essentially of two plane mirrors, enclosed in a box open at each end, placed back to back, inclined at an angle of 45° to the horizon, and forming a right angle with each other. The lights to be examined are arranged at a convenient distance apart, and the photometer placed between them, so that the light from each shall fall fairly upon one of the inclined mirrors, and, thus diverted into a perpendicular direction, it is received upon a piece of white paper, of even texture, which closes an opening in the top of the box, where their respective intensities can be conveniently compared. The instrument is moved in the line of the lights until the intensities are equalized, when the distances from the centre of the photometer to the centres of the lights are measured, and the light estimated as proportional to the square of the distance.

Four lamps were submitted to the committee for examination by Mr. Bennett, which were numbered, for convenient reference, according to the diameter of the wicks, No. 1 being the largest.* The standard used was the gas argand burner in the committee room, which was ascertained to burn 4.25 cubic feet of gas per hour, the expense of which, at the present price of gas, is 1.4875 cents per hour. As the experiments were not made with the purpose of deciding upon the economical value of gas, the committee think it but fair to observe that no attempt was made to determine whether more economical gas-burners were not in use, or might not be devised.

Mr. Cornelius kindly furnished to the committee, for their experiments, two solar lamps, (Nos. 1 and 2,) and an argand lamp, fitted with a cap to direct the outer current of air upon the flame, (which lamp is called in the table a semi-solar lamp.) In reference to which it is to be observed, that the solar lamp No. 2 was of a pattern which has been for some time abandoned by the makers, as affording a less economical result than that given by the new form.

The committee have also incorporated into their report the last series of comparative experiments made by them with the camphine lamps of Carr, Dyott, and Gould; and the result of experiments to determine the comparative values of sperm and lard oil, when burned in the Carcel lamp.

The Carcel lamps, Nos. 1 and 3, were burned with fall strained oil, at 90 cents per gall.; Nos. 2 and 4 with winter strained oil, at $1 00 per gall.

The solar lamp, No. 2, and the semi-solar, with winter strained; No. 1, with fall strained oil.

The following table gives the result of these experiments; the economical value being estimated as the intensity divided by the expense, or the relative quantity of light for the same expense.

* These lamps are numbered by Mr. Bennett as follows:

No. 1 of the Committee is			No. 15 of Mr. Bennett.		
" 2	"	"	13	"	
" 3	"	"	12	"	
" 4	"	"	10	"	

Table, showing the relative intensities, the quantity consumed, the duration of experiment, the cost of material, the expense per hour, and the economical value of different lights.

Note.—The economical value is estimated as the quantity of light at the same expense; that is, as the intensity divided by the expense.

		Intensity.	Quantity consumed in pints.	Duration of experiment in hours.	Cost of material per pint.	Time of consum'n of 1 pint in hours.	Expense per hour in cents.	Qu'n'y of light at same expense.
Gas,		1.					1.4875	1.
Carcel	No. 1	2.152	.92	5.8	11.25	6.32	1.78	1.8
	" 2	1.1	.766	7.	12.5	9.14	1.27	1.2
	" 3	.93	.766	7.	11.25	9.14	1.23	1.1*
	" 4	.69	.422	6.15	12.5	14.60	.86	1.2
Solar	" 1	2.13			11.25		1.85	1.71
	" 2	1.4	.481	4.05	12.5	8.42	1.48	1.4
Semisolar		1.152	.6	4.05	12.5	6.75	1.85	.93
Camp.	Carr	1.8	.25	2.50	7.8	10.	.78	3.4
	Dyott	1.69	.28	2.63	7.8	9.40	.83	3.
	Gould	1.75	.31	2.66	7.8	8.53	.91	2.86

The consumption and expense in this table were determined by an independent experiment. The solar lamp, No. 1, was introduced from after experiments.

The following experiments were instituted by the committee to determine the comparative values of sperm and lard oil, as burned in the Carcel lamp, which, from its construction, requires a better oil for its satisfactory exhibition than ordinary lamps.

The experiments were conducted in two similar Carcel lamps, and were continued, the first during eight, the second for nine, hours.

The lamp which was used in the first experiment for the sperm, was, in the second, used for the lard oil, and vice versa.

Experiment 1.—The oils used were lard oil, at 80 cents per gallon, and fall pressed sperm oil, at 90 cents per gallon. The experiment lasted eight hours, and the intensity was examined every half hour.

	11*h.* 40*m.*		5*h.* 05*m.*	5*h.* 30*m.*	6*h.*	6*h.*30*m.*	7*h.*	*Av'ge.*
Sperm oil	1.	no ch'nge until 5 o'clock	1.	1.	1.	1.	1.	1.
Lard oil	.72		.5	.46	.374	.41	.396	.63

Oil consumed, sperm 13.7502 oz.; lard oil, 12.5 oz.

* An after experiment with this lamp demonstrated to the satisfaction of the committee, that its less economical value was owing to its being used with too high a chimney. When tried with a better chimney, it gave the same result, as to economical value, with No. 2.

Experiment 2.—The lamps were reversed; that is, after being emptied and carefully drained, the one which had been used with sperm oil was filled with lard oil, and vice versa.

	11*h.*	4*h.*	5*h.*	5*h.*30*m.*	6*h.*	6*h.*30*m.*	7*h.*	7*h.*30*m.*	8*h.*	*Av'ge*	*Av. of both*
Sperm oil	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
Lard oil	.86	1.81	1.5	.83	1.	.86	.66	.52	.35	1.09	.86

Duration of the experiment, nine hours. Oil consumed, sperm 13.5 oz.; lard, 14.5 oz.

After the conclusion of the experiment, the lamp containing the sperm oil was compared with the gas standard, and gave the following comparative intensity—gas 1., Carcel 1.2; and as it was the lamp marked No. 2, in Table B, it demonstrates the admirable steadiness of these lamps, when burned during considerable periods of time.

The irregularity and diminution of light shown by the lard oil, and its consequent less economical value, was owing to the fact of the formation of a long and hard crust upon the wick, which finally reduced the light so far as to induce the committee to close the experiment. But farther experiments, with lamps of other constructions, would be necessary to enable us to decide upon the general question of the comparative values of lard and sperm oil, as burned in such.

In consequence of the representation made to the committee that the solar lamp heretofore used in their experiments, (marked No. 2, in Table B,) was not a fair average specimen of that kind of lamp, two new series of experiments were undertaken with a lamp selected by the makers, and in the presence of those interested in both lamps. The following were the results.

Experiment 1.—Oil furnished by the makers of the solar lamp.

	1*h.*	*h. m.* 1 30	2*h.*	*h. m.* 2 30	3*h.*	*h. m.* 3 30	4*h.*	*h. m.* 4 30	5*h.*	*h. m.* 5 30	6*h.*	*h. m.* 6 30	*Average.*
Carcel lamp,	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
Solar lamp,	.85	1.	1.	1.	1.1	1.2	1.06	1.1	1.1	.85	.975	1.1	1.03

It was evident, from the irregular behaviour of the Carcel lamp, that the oil was not favorable to its use.

Experiment 2.—The same lamps were used, with oil furnished by the agent for the Carcel lamp.

	12*h.*	*h. m.* 12 30	1*h.*	*h. m.* 1 30	2*h*	*h. m.* 2 30	3*h.*	*h. m.* 3 30	4*h.*	*h. m.* 4 30	5*h.*	*h. m.* 5 30	6*h.*	*Av.*	*Av. of* 2 *exp'ts.*
Carcel,	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
Solar,	.957	.87	.87	1.	1.	.99	.975	.975	.975	.975	.96	.96	.97	.95	.99

In conclusion, without presuming to decide upon the relative merits of different lighting materials, the committee would make the following general remarks upon their evident advantages and disadvantages.

The gas possesses the advantage of giving a very bright and continuous light, not subject to variation when burned during a long period of time; in our city, at least, free from all obnoxious smell, or smoke, and requiring no trouble, care, or time, in its arrangement; and is cleanly. Its disadvantage is, that it is a fixed light, and can be used only at points previously determined upon.

The camphine possesses a remarkable intensity and high lighting power, with a brilliant white flame, and, from its cheapness, presents strong claims, on the score of economy, upon public notice. Its disadvantages are, the great inflammability of the material, the liability to annoyance from its disagreeable smell, and the injurious and unendurable smoke which proceeds from the lamp when out of order, or not properly regulated.

The Carcel lamps, although, from their construction, expensive, give an exceedingly steady, long enduring, and bright light, and are characterized by beauty of form, and total absence of shadow. They give, also, a highly economical result from the quantity of oil burned. In order to produce the best results, they, however, require the finer qualities of oil.

The solar lamp, although not so steady in its light as the Carcel, has a flame which, in the best specimens of this lamp, approaches very nearly, if it do not equal, that of the Carcel, in intensity. It is comparatively cheap, simple in its construction, not liable to get out of repair, and easily cleansed.

By order of the Committee,

Jan. 12*th*, 1843. WILLIAM HAMILTON, Actuary.

Practical & Theoretical Mechanics & Chemistry.

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

Cool Sweating Process in Tanning.

It is a matter of much regret, that, at this moment, when every other art and manufacture has been benefitted by the discoveries of science, the manufacture of leather seems to stand, to a great extent, unimproved and unchanged by the progress made in chemistry, and uninfluenced by the rapid march of other branches of art towards perfection. Old modes of procedure have, in every other department of the producing interest, been discarded, and the entire processes revolutionized by the light thrown upon them from the discoveries in chemical and mechanical science. Though the investigating chemist has endeavored to improve the mode of manufacture, and much light has been shed upon that part of the process which he has examined,

yet the tanner has done little or nothing to aid his investigations, being too generally content to follow the practices of his fathers, often erroneous, and founded upon false theory, or a mere hap-hazard method. It is true, that, in the mechanical processes, much improvement has been made upon the modes practised by our forefathers. We may trace them from early antiquity, when the flail served to break the rough bark for soaking in the pit, down through the stone crushing and breaking, by its revolution, the bark beneath it, to the adoption of the cast-iron mill propelled by steam, by water, or other powerful agent. The application of steam has been thought, by some, to aid materially in the extraction of the tannin; but that this is true, or that tanning with warm liquors, or with liquors containing tannin thus extracted, improves the quality of the leather, admits of a doubt. To these may be added various kinds and descriptions of reels, rolling machines, and other modes of lessening labor and expense, to describe all which, with the numerous attempted improvements, would require a volume. But it appears that these are all mere mechanical improvements, highly valuable, it is true, as far as they go, originating in the desire of the tanner to lessen those expenses which were more obvious to his understanding than the equally important losses which he was sustaining by erroneous processes in the chemical department of his operations.

That the manufacture of leather should have made such slow progress, is rather surprising when we consider the vast utility and extensive use of the article in every department of civilized life. The Hon. Gideon Lee, in his lectures on tanning, has truly remarked that, "In point of necessity, few manufactures surpass it. Leather, indeed, seems to enter into the uses of every other trade, every family, every person; nor does it stop at the useful—a large portion of ornamental furniture, equipage and dress, admit and require this commodity, in some of its numerous forms. Whichever way we look or move, we can not fail to see this indispensable article in use." Upon inquiry into the history of the progress of this art, we cannot find that any tolerably correct notion of the philosophy of tanning existed until within the last forty years. Prior to this, it was deemed a mere mechanical process, and the attention of chemists had never been turned to the investigation of the subject. That leather was a definite compound of the gelatine and albumen of the hide with the tanning principle, was unknown and unsuspected. It is true that some improvements have originated in a more definite knowledge of the action of the substances concerned. Of the tanning, properly so called, it is not our purpose at present to speak; but will confine our attention to that part of the process connected with the preparation of the hide for

combining most advantageously with the tannin; we allude to the liming and bating, or the unhairing and cleansing, preparatory to introduction to the liquor, which is a solution of the tanning principle. The mode extensively used in England, upon the continent, and in the United States, is that of steeping the hides in a solution, or more properly a milk, of lime, in which they are allowed to remain from one to three or more weeks, according to the state of the weather and the texture of the hide, until they present the appearance which experience has taught is proof of the proper action of the lime. This has the effect to loosen the hair and epidermis of the skin, and render it easily removable by the after rubbing down, by means of a knife, upon a beam, or block. Another mode of producing the same result is that of suspending the hides in a close chamber, heated a little above the ordinary temperature of the atmosphere by a smouldering fire. In this case, the epidermis becomes loosened by incipient putrefaction. A so-called sweating process is in use in Germany, and by some applied in this country; but it, as well as the preceding, is attended with much risk—so much so as to preclude their extensive adoption. By the last, the hides are laid in a pack, or pile, and covered with tan, or other imperfect conductor of heat, in order to confine the heat generated by the spontaneous decomposition of the gelatine, or other substance of the skin, and roots of the hair.

To the investigation of this very important part of the tanning process, chemists seem to have given little, or no, attention; and the practical workman has derived from them no insight into the true nature of the operation, and, consequently, has not improved it to that extent which is desirable. The action of lime upon the texture of the skin, so far as the loosening of the hair is concerned, is not involved in much obscurity; but the other changes effected upon the hide, which remain permanent, and influence, to a considerable extent, the quality of the leather, have never been satisfactorily explained. Neither have the chemists yet been able to give any satisfactory elucidation of the mode of operation of the bate, (as technically termed,) which consists of a solution of the muriates of ammonia and soda, &c., from the excrements of pigeons and domestic fowls. That the muriates are decomposed by, and combine with, the lime, rendering it more soluble, is most probably the true explanation of that part of the process; but how the fermentation produced affects the quality of the leather is not clear, unless we suppose that a large portion of the gelatine and albumen of the hide are removed. Though this is highly probable, yet we believe it is not generally admitted by tanners.

The Hon. Gideon Lee, in his lectures on tanning, remarks, "I be-

lieve much of the original gelatine of our hides is never combined with the tannin, but is wasted, actually extinguished, or incapacitated, or perhaps both, in the process of the manufacture; for I have not a doubt that, if it were possible to bring every particle of hide, the moment it is prepared for the handler, into conjunction with the tannin, as chemists are able to do with the solutions of both, the results would give nearly two hundred pounds (probably one hundred and eighty) of leather from one hundred pounds of perfectly dry hide, when cleansed from all extraneous appendages." "But, as this is impracticable—as we must retain the original organic form of the hide, in order to make leather of it—it becomes our business to devise and adopt such saving modes of process as will waste the least, and save the greatest, quantity of the gelatinous substance of the hide." No doubt a vast saving of the gelatinous parts, and, consequently, a much increased amount of leather, might be made by adopting new modes of preparing the hides for the liquors. Further, we can say with confidence, that such saving has been made, and the quantity of leather produced has very nearly approached that which chemists consider the greatest amount possible. "Saving," he truly remarks, "should be the order of the day," and we may add, that he who, by the application of scientific principles to the manufacture of leather, should thereby add to the value of the article produced, and, consequently, to the general comfort and wealth, should justly be considered a benefactor to his country. When we consider the immense amount which has been annually lost for ages, for all practicable purposes, we are appalled at the sum, and our surprise increases that tanners have not busied themselves to lessen this immense drain upon their profits.

Among the evils of the old process may be enumerated that which arose from the energetic action of the agents made use of, and the extreme caution necessary to be observed in their application. By this process, still extensively used, the dry hides are subjected to the operation of the fulling stocks, which, by their powerful action upon the fibres, soften and extend their particles, causing them to move on each other, and, we believe, if long continued, opening the pores, and removing a considerable portion of the soluble matter of the hide, causing that "softness, limberness, and thinness," which is sometimes complained of in leather which has been otherwise well managed. A certain degree of softness appears to be absolutely necessary for the proper action of the lime and bate, and for the just incorporation of the tannin with the hide. Against the liming process a strong objection may be brought, in its injurious action upon the particles of gelatine and albumen of the hide. That a substance so powerful in its affini-

ties, and capable of decomposing so rapidly most animal matter, should act with injurious effects upon the moist, porous substance of the softened hide, can scarcely be doubted by any who have had any practical experience on the subject. The effects this agent produces in expanding and stretching the fibres of the hide, thereby drawing them from their original position, and, consequently, weakening their texture, must be obvious—"swelling, as it does, the body of the hide to double its original thickness." "Every tanner knows that high limed leather is loose, weighs light, and wears out quickly;" and may we not with much probability suppose, that its injurious effects are produced in a proportionate degree by the "low liming process?"

The evils resulting from the use of this agent are doubtless to be ascribed to its decomposition of the albuminous and gelatinous parts, and that thereby an amount of these substances is destroyed, of which we can form no adequate idea. Not only does the tanner thus lose those parts which would have combined and formed leather, but that which is formed is rendered less valuable, owing to its decreased solidity, toughness, and porosity.

Without doubt, the injurious effects produced by liming are increased and heightened by the after process of bating, which is intended to extract the lime, and bring down the skin to its original thickness, by soaking or drenching, as before alluded to. The muriates, &c., in solution, which render the lime more soluble, and thus easily removed, carry off a portion of the glue, &c., and the fermentation induced by the decomposition of the animal matters of the bate also materially assists in the destruction of these easily decomposed components of the hide. That a fermentation takes place, is proved by the rapid action of the bate in destroying the grain side of the skin, or hide, during the warm days of summer, if not properly attended, and suffered to proceed too far. Another objection which should not be passed over, lies in the extremely unpleasant scent arising from the putrefaction of animal matter, which is inseparably attached to the clothing and persons of the workmen engaged in this branch of the business.

The evils arising from the old, and still practiced, methods being thus made sufficiently apparent to the understanding of every practical man who has not already appreciated them, and learned from sad experience their reality, we are prepared for the reception of a process which, to a great extent, in the estimation of those who have applied it, removes the difficulties under which the tanner has labored. This is that which has been erroneously denominated the "cool sweating process for unhairing hides and skins," in contradistinction to that which is practiced in Europe, and, to some extent, in this

country, and is called the "warm sweating," and which has been before described. It will be remembered that the effects produced by the latter method, in loosening the hair, are due to the putrefaction engendered by their being placed in piles, or exposed to artificial heat, and that it is attended with much risk.

The so-called "cool sweating process," and apparatus made use of, are thus described. First, a vault, or pit, should be prepared for the reception of the hides, which, for convenience sake, should be twelve feet long, twelve feet deep, and ten feet wide. The walls may be built of stone, or a frame, and planked. There should be an alley, or vestibule, for entrance, not less than six feet long, having a door at each end, the outer one made double, and filled in with tan, to prevent the communication of warm dry air from without. A ventiduct, made of plank, ten or twelve inches square, should extend from the centre of the bottom of the vaults, three or four rods therefrom, and placed not less than four feet below the surface of the ground. This serves both as a drain for discharging the water of the vault, and to admit damp, cool air, to supply the place of that which has become rarefied, and thus keep up a current through the ventilator at top. The ridge of the roof may be level with the surface of the ground; on the ridge, and extending its whole length, set up two planks, edgewise, two inches apart. The space between these is to be left open, but cover the remainder of the roof with earth to the depth of not less than three feet. The covering of earth upon the vault and drain is to preserve a low temperature for the hides, so that they may unhair without tainting. Spring water should be conducted, either in pipes or logs, around the angles formed by the ceiling with the walls of the vault, from which water should be allowed to flow in small quantities, either forming a spray, or falling so as to raise a mist, or vapor, and saturate the atmosphere of the vault. The temperature of spring water is generally about 50° Fahr. Water evaporating at all temperatures, it is plain that, if a constant supply be afforded, this evaporation, by requiring a large portion of heat, would keep the temperature of the vault nearly uniform. To suspend the hides in the pit, place three bars lengthwise, at equal distances, near the ceiling, with iron hooks, two or three inches apart, inserted therein. Soak the hides as usual for breaking, then hang them singly upon the hooks by the butt, spreading them fully open. In the course of a few days, when the hair begins to loosen upon the upper parts, take them down, raise the middle bar, and hang them by the other end until they will easily unhair. The hides should not be broken until they are taken from the vault, and ready to unhair. In a good vault, where the thermometer ranges from 44° to 56° Fahrenheit, which it should

never exceed, and where there is a free circulation of *damp* air, hides generally require, for unhairing, from six to twelve days. When the temperature falls below 44°, the ventilator should be partially closed; and when it rises above 56°, *cold damp* air must be forced in, or an increased quantity of cold spring water may be thrown from a hose, or otherwise.

If this process is properly and carefully conducted, hides will be received by the tanner, from the beamsman's hands, free from all extraneous matter, and retaining nearly all their gelatine, or glue, with the albuminous and fibrous matter of the organized hide. The action of the agents employed in the cool sweating process appears to be confined to the *surface*, or *grain*, of the skin, expanding the outer portion, and softening the roots of the hair, thus rendering their extraction more easily effected. In opposition to some who, without due examination, have pronounced this a putrefactive process, and consider it as differing in no important particular from that formerly made use of, and which was attended with such imminent risk, we, after considerable experience and investigation, are brought to the conclusion that the effect produced by what is called the "cool sweating process," is due to the *softening* action of the vapor, and that it is a simple case of absorption and swelling of the tissues of the skin, and roots of the hair. Various circumstances combine to strengthen us in this opinion, the most obvious of which are the following, viz.: We believe it to be the opinion among chemists that the putrefactive fermentation, or that which is vulgarly called tainting, is always attended by the formation of ammonia, (spts. hartshorn, a substance readily perceived by the senses,) and that when this cannot be recognized in the vault, or chamber, in which the process is conducted, we are warranted in supposing it is not produced, and that, consequently, this fermentation does not take place. That the action of the vapor is confined to the surface of the hide, is proved by its increased weight, when prepared by this process, over that by liming, and the consequent gain of leather; for whereas, by the old liming method, thirty to forty per cent. gain upon the original weight of the dry hide was considered a good increase, now, by the cool sweating, a gain of from fifty to seventy, and even eighty, per cent. is often obtained—thus showing incontestably that a great amount of the softer portions of the hide, which were formerly lost, are now retained within it by this method of unhairing. This result would not to the same extent be produced, if the process was putrefactive, as thereby much of the substance must be removed, or brought into a condition to be acted upon by the solvents to which they are subjected. We may add, that

those chemists who have attentively examined it, have pronounced it a simple case of absorption and softening.

The advantages which this process presents, must be apparent to the understanding of every unprejudiced practical tanner, who is at the same time acquainted with the chemical nature of the action of the substances used in his art. To the tanner, who believes that all the *glue* must be extracted from the hide in order to make good leather, this method would appear erroneous; but who, that has any knowledge of the composition of leather, so supposes? or who would consider the objection of such as worthy of regard?

The continuance of this method, where once adopted, is the best proof of its utility, and that it realizes, in practice, all that was expected of it. It is practiced almost universally in the large tanneries of New York, Maine, New Hampshire, and, to some extent, in northern Pennsylvania. Perhaps the best mode of illustrating the advantages to be derived from the process, will be from evidence given forth by tanners who have adopted it, rather than by expressions in general terms, unsupported by testimony. This mode of proof, though often deceptive, and, on that account, not much confided in, in this case will not be doubted, coming, as it does, from those who are known to the trade, and acknowledged by them to be men of honor and veracity.

Col. W. Edwards, who, as the Hon. Gideon Lee states, "has been the originator of many important improvements in the mechanical department of tanning," has certified that he has been a tanner for twelve years, and has tanned upwards of forty thousand sides per annum—has used this method, and knows that there was a saving of *two-thirds* the expense of working in, and *twenty-five per cent. gain* in weight over that produced by liming. And, moreover, that he has made diligent inquiry of tanners, from different parts of this country and Europe, and could never find a single instance where a similar mode was practiced.

John Spencer, of Onondaga county, N. Y., late member of the Legislature, states that "the hides are prepared for the bark with *half* the labor, and, when prepared, tan fully as fast, weigh heavier, and wear much longer, than when prepared by liming."

Thos. Updegraff, of Williamsport, tanner, states that "a tanner can accomplish as much in working in, in ten days, by this method, as could be done in one month by the old way of liming."

W. W. Edwards, of Hunter, Greene county, N. Y., testified that, by memoranda kept at the time, and accurately made up, the expense of working in, or preparing for the bark liquor, by the old liming process, was twelve and a half cents per side; and that the expense

of the same operation by the new mode, as ascertained in the same manner, was four and two-thirds cents per side. That the hides were of similar kinds, and that all his leather was disposed of in New York, and that, if well manufactured, gains more in weight, is of superior texture, fineness, and solidity, if worked in by the sweating process, after being well softened, than by any liming process he has ever known.

E. J. Stimson, formerly (in 1835) of Hunter, Greene county, N. Y., testified that he had tanned, in four years, upwards of 75,000 sides of leather—that he made 62½ per cent. gain on Oronoco hides, 53 per cent. on Vera Cruz, 51 on Mexican, and 55 per cent. on Buenos Ayres, all of which were sent to New York market for disposal; and that the leather manufactured by this process gains more in weight, the proportion of sides stamped by inspectors "*damaged*," is less; also, that they will tan faster, if properly attended to, than when prepared by the liming process.

This mode of unhairing can be applied with like success to calf skins, and upper, as to sole, leather, with some modifications in the tanning; first proved by the late Ebenezer Shore, and brought into general use by Nathan T. Davis. The evidence of the successful application of these improvements, we have in the statements of the following tanners.

N. T. Davis, of Levant, Maine, says that he knows it to be as valuable for calf skins and upper, as for sole, leather, and that his leather has been pronounced of superior quality by the Boston consumers.

Benj. Cutter, of Jaffray, N. H., deposed that he has manufactured, for some years past, sole, upper leather, and calf skins—that he finds the calf skins gain fifteen per cent. more by weight of the manufactured stock, than by the liming process; and those to whom he has sold his skins, have pronounced them good.

Ezra W. Avery, of Grafton, N. H., states that calf skins and upper leather, prepared by this process, are more impervious to water, possess more toughness, strength, and durability, than by liming, and that he has fully tested its value by working, wearing, and selling it to his customers.

Other testimony could be produced, all confirming the above statements as regards the reduction of expense, the ease of working, and superiority of leather produced. But the above we considered sufficient to satisfy any unprejudiced tanner of the correctness of the process, confirmed as it is by hearsay evidence, which must have arrested his attention.

We would call the attention of the tanners of Pennsylvania and Maryland to the consideration of this subject. Its importance they

cannot fail to perceive. Interest, that prime mover to action, should incite them to investigation. St. Paul has said, "Prove all things—hold fast to that which is good." Let not prejudice blind, or mistaken opinion lead you astray. We know that prejudice in favor of old methods is as deeply rooted in the mind of the tanner, as in that of the farmer. But, thanks to that free spirit of inquiry which has penetrated even the mysteries of agriculture, the day is opening when the tanner shall no longer acknowledge ignorance of the principles concerned in his art, and when true modes of procedure will take the place of those methods which have been shown to be erroneous, wasteful, and offensive. S. T.

On some Peculiar Changes in the Internal Structure of Iron, independent of, and subsequent to, the several Processes of its Manufacture. *By* CHARLES HOOD, Esq., F.R.A.S., &c.*

The important purposes to which iron is applied have always rendered it a subject of peculiar interest; and at no period has its importance been so general and extensive as at the present time, when its application is almost daily extending, and there is scarcely anything connected with the arts, to which, either directly or indirectly, it does not in some degree contribute. My object in the present paper is to point out some peculiarities in the habitudes of iron, which appear almost wholly to have escaped the attention of scientific men, and which, although in some degree known to practical mechanics, have been generally considered by them as isolated facts, and not regarded as the results of a general and important law. The circumstances, however, well deserve the serious attention of scientific men, on account of the very important consequences to which they lead. The two great distinctions which exist in malleable wrought-iron are known by the names of "red-short" and "cold-short" qualities. The former of these comprises the tough, fibrous iron, which generally possesses considerable strength when cold; the latter shows a bright crystalized fracture, and is very brittle when cold, but works ductile while hot. These distinctions are perfectly well known to all those who are conversant with the qualities of iron; but it is not generally known that there are several ways by which the tough red-short iron becomes rapidly converted into the crystalized, and by this change its strength is diminished to a very great extent.

The importance which attaches to this subject, at the present time, will not, I think, be denied. The recent accident on the Paris and Versailles Railway, by which such a lamentable sacrifice of human life has occurred, arose from the breaking of the axle of a locomotive engine, and which axle presented, at the fractured parts, the appear-

* Read before the Institution of Civil Engineers, June 21, 1842, and communicated by the author to the twenty-first volume of the Philosophical Magazine, from which periodical we have extracted it.

ance of the large crystals, which always indicate cold-short and brittle iron. I believe there is no doubt, however, that this axle, although presenting such decided evidence of being, at the time of this accident, of the brittle cold-short quality, was at no distant period tough and fibrous in the highest degree; and, as the French government have deemed the matter of sufficient importance to be inquired into by a special commission, I trust that some remarks on the subject will be interesting to the members of the Institution of Civil Engineers. I propose, therefore, to show how these extraordinary and most important changes occur, and shall point out some, at least, of the modes by which we can demonstrate the truth of this assertion by actual experiment.

The principal causes which produce this change are percussion, heat, and magnetism; and it is doubtful whether either of these means *per se* will produce this effect; and there appear strong reasons for supposing that, generally, they are all in some degree concerned in the production of the observed results.

The most common exemplification of the effect of heat in crystalizing fibrous iron, is by breaking a wrought-iron furnace bar, which, whatever quality it was of in the first instance, will, in a short time, invariably be converted into crystalized iron; and by heating, and rapidly cooling by quenching with water a few times, any piece of wrought-iron, the same effect may be far more speedily produced.

In these cases, we have at least two of the above causes in operation—heat and magnetism. In every instance of heating iron to a very high temperature, it undergoes a change in its electric, or magnetic, condition; for, at very high temperatures, iron entirely loses its magnetic powers, which return, as it gradually cools to a lower temperature. In the case of quenching the heated iron with water, we have a still more decisive assistance from the electric and magnetic forces; for Sir Humphrey Davy long since pointed out* that all cases of vaporization produced negative electricity in the bodies in contact with the vapor; a fact which has lately excited a good deal of attention, in consequence of the discovery of large quantities of negative electricity in effluent steam.

These results, however, are practically of but little consequence; but the effects of percussion are at once various, extensive, and of high importance. We shall trace these effects under several different circumstances.

In the manufacture of some descriptions of hammered iron, the bar is first rolled into shape, and then one-half the length of the bar is heated in a furnace, and immediately taken to the tilt-hammer and hammered; and the other end of the bar is then heated and hammered in the same manner. In order to avoid any unevenness in the bar, or any difference in its color, where the two distinct operations have terminated, the workman frequently gives the bar a few blows with the hammer on that part which he first operated upon. That part of the bar has, however, by this time become comparatively cold; and if this cooling process has proceeded too far when it receives this

* Davy's Chemical Philosophy, p. 138.

additional hammering, that part of the bar *immediately* becomes crystalized, and so extremely brittle that it will break to pieces by merely throwing it on the ground, though all the rest of the bar will exhibit the best and toughest quality imaginable. This change, therefore, has been produced by percussion, (as the primary agent,) when the bar is at a lower temperature than a welding heat.

We here see the effects of percussion in a very instructive form. And it must be observed that it is not the excess of hammering which produces the effect, but the absence of a sufficient degree of heat at the time the hammering takes place; and the evil may probably be all produced by four or five blows of the hammer, if the bar happens to be of a small size. In this case we witness the combined effects of percussion, heat, and magnetism. When the bar is hammered at the proper temperature, no such crystalization takes place, because the bar is insensible to magnetism. But as soon as the bar becomes of that lower degree of temperature at which it can be affected by magnetism, the effect of the blows it receives is to produce magnetic induction; and that magnetic induction, and consequent polarity of its particles, when assisted by further vibrations from additional percussion, produces a crystalized texture. For it is perfectly well known that, in soft iron, magnetism can be almost instantaneously produced by percussion; and it is probable that, the higher the temperature of the bar at the time it receives the magnetism, the more likely will it be to allow of that re-arrangement of its molecules which would constitute the crystalization of the iron.

It is not difficult to produce the same effects by repeated blows from a hand-hammer on small bars of iron; but it appears to depend upon something peculiar in the blow, which, to produce the effect, must occasion a complete vibration among the particles in the neighborhood of the part which is struck. And it is remarkable that the effects of the blows, in all cases, seem to be confined within certain limited distances of the spot which receives the strokes. Mr. Charles Manby has mentioned to me a circumstance which fully bears out this statement. In the machine used for blowing air at the Beaufort Iron Works, the piston-rod of the blowing cylinder, for a considerable time, had a very disagreeable jar in its motion, the cause of which could not be discovered. At last the piston-rod broke off quite short, and close to the piston, and it was then discovered that the key had not properly fastened the piston and the rod together. The rod, at the fracture, presented a very crystalized texture; and, as it was known to have been made from the very best iron, it excited considerable surprise. The rod was then cut at a short distance from the fracture, and it was found to be tough and fibrous in a very high degree; showing what I have already pointed out, that the effects of percussion generally extend a very short distance. In fact, we might naturally expect, that, as the effect of vibration diminishes in proportion to the distance from the stroke which produces it, so the crystalization, if produced by this means, would also diminish in the same proportion. The effect of magnetism alone may also be estimated from this circumstance. The rod would, of course, be magnetic throughout

its whole length, this being a necessary consequence of its position, independent of other circumstances; but the necessary force of vibration among its particles only extended for a short distance, and to that extent only did the crystalization proceed. The effect of magnetism in assisting the crystalization, I think it unnecessary to dwell upon, as the extensive use of galvanic currents in modern times has fully proved their power in crystalizing some of the most refractory substances; but, by themselves, they are unable to produce these effects on iron, or, at least, the operation must be extremely slow.

Another circumstance which occurred under Mr. Manby's observation confirms, generally, the preceding opinions. A small bar of good tough iron was suspended and struck continuously with small hand-hammers, to keep up a constant vibration. The bar, after the experiment had been continued for some considerable time, became so extremely brittle, that it entirely fell to pieces under the light blows of the hand-hammers, presenting throughout its structure a highly crystalized appearance.

The fracture of the axles of road-vehicles of all kinds is another instance of the same kind. I have, at different times, examined many broken axles of common road-vehicles, and I never met with one which did not present a crystalized fracture; while it is almost certain that this could not have been the original character of the iron, as they have frequently been used for years with much heavier loads, and at last have broken without any apparent cause, with lighter burdens and less strain than they have formerly borne. The effects, however, on the axles of road-vehicles are generally extremely slow, arising, I apprehend, from the fact that, although they receive a great amount of vibration, they possess a very small amount of magnetism, and are not subject to a high temperature. The degree of magnetism they receive must be extremely small, from their position and constant change with regard to the magnetic meridian, the absence of rotation, and their insulation by the wood-spokes of the wheels. Whether the effects are equally slow with iron wheels used on common roads, may perhaps admit of some question. With railway axles, however, the case is very different. In every instance of a fractured railway axle, the iron has presented the same crystalized appearance; but this effect, I think, we shall find is likely to be produced far more rapidly than we might at first expect, as these axles are subject to other influences, which, if the theory here stated be correct, must greatly diminish the time required to produce the change in some other cases. Unlike other axles, those used on railways rotate with the wheels, and, consequently, must become, during rotation, highly magnetic. Messrs. Barlow and Christie were the first to demonstrate the magnetism by rotation produced in iron, which was afterwards extended by Messrs. Herschel and Babbage, to other metals generally, in verifying some experiments by M. Arago. It cannot, I think, be doubted that all railway axles become, from this cause, highly magnetic during the time they are in motion, though they may not retain the magnetism permanently. But, in the axles of locomotive engines, we have yet another cause which may tend to increase the effect. The

vaporization of water and the effluence of steam have already been stated to produce large quantities of negative electricity in the bodies in contact with the vapor; and Dr. Ure has shown* that negative electricity, in all ordinary cases of crystalization, instantly determines the crystaline arrangement. This, of course, must affect a body of iron in a different degree to that of ordinary cases of crystalization; but still we see that the effects of these various causes all tend in one direction, producing a more rapid change in the internal structure of the iron of the axle of a locomotive engine, than occurs in almost any other case.

Dr. Wollaston first pointed out that the forms in which native iron is disposed to break, are those of the regular octahedron and tertrahedron, or rhomboid, consisting of these forms combined. The tough and fibrous character of wrought-iron is entirely produced by art; and we see in these changes that have been described, an effort at returning to the natural and primal form—the crystaline structure, in fact, being the natural state of a large number of the metals; and Sir Humphrey Davy has shown that all those which are fusible by ordinary means, assume the form of regular crystals by slow cooling.

The general conclusion to which these remarks lead us, appears, I think, to leave no doubt that there is a constant tendency in wrought iron, under certain circumstances, to return to the crystalized state; but that this crystalization is not necessarily dependent upon time for its development, but is determined solely by other circumstances, of which the principal is undoubtedly vibration. Heat, within certain limits, though greatly assisting the rapidity of the change, is certainly not essential to it; but magnetism, induced either by percussion, or otherwise, is an essential accompaniment of the phenomena attending the change.

At a recent sitting of the Academy of Sciences at Paris, M. Bosquillon made some remarks relative to the causes of the breaking of the axle on the Versailles railroad; and he appears to consider that this crystalization was the joint effect of time and vibration, or, rather, that this change only occurs after a certain period of time. From what has here been said, it will be apparent that a fixed duration of time is not an essential element in the operation; that the change, under certain circumstances, may take place instantaneously; and that an axle may become crystalized in an extremely short period of time, provided that vibrations of sufficient force and magnitude be communicated to it. This circumstance would point out the necessity for preventing, as much as possible, all jar and percussion on railway axles. No doubt one of the great faults of both engines and carriages of every description—but particularly the latter—is their possessing far too much rigidity; thus increasing the force of every blow produced by the numerous causes incidental to railway transit, by causing the whole weight of the entire body in motion to act by its momentum, in consequence of the perfect rigidity of the several parts, and the manner of their connexion with each other, instead of such a degree of elasticity as would render the different parts nearly inde-

* Journal of Science, vol. v, p. 106.

pendent of one another, in the case of sudden jerks, or blows; and which rigidity must produce very great mischief, both to the road, and to the machinery moving upon it. The looseness of the axles in their brasses must also be another cause which would greatly increase this evil.

Although I have more particularly alluded to the change in the internal structure of iron with reference to the effects on railway axles, it need scarcely be observed that the same remarks would apply to a vast number of other cases, where iron, from being more or less exposed to similar causes of action, must be similarly acted upon. The case of railway axles appears to be of peculiar and pressing importance, well deserving the most serious consideration of scientific men, and particularly deserving the attention of those connected with railways, or otherwise engaged in the manufacture of railway machinery, who have the means of testing the accuracy of the theory here proposed. For if the views I have stated be found to harmonize with the deductions of science, and to coincide with the results of experience, they may have a very important effect upon public safety. It may be observed, on the other hand, however, that, at the present time, all railway axles are made infinitely stronger than would be necessary for resisting any force they would have to sustain in producing fracture, provided the iron were of the best quality; and to this circumstance may perhaps be attributed the comparative freedom from serious accidents by broken axles. The necessity for resisting flexure and the effects of torsion, are reasons why railway axles never can be made of such dimensions only as would resist simple fracture; but it would be very desirable to possess some accurate experiments on the strength of wrought iron in different stages of its crystalization, as there can be no doubt that very great differences exist in this respect; and it is probable that, in most cases, when the crystalization has once commenced, the continuance of the same causes which first produced it goes on continually increasing it, and thereby further reduces the cohesive strength of the iron.

[Several samples of broken railway axles accompanied this paper, and were exhibited at the meeting. In some of them, the same axle was broken in different places, and showed that, where the greatest amount of percussion had been received, the crystalization of the iron was far more extensive than in those parts where the percussion had been less.]

Remarks.—Mr. Moreland had frequently noticed that pins for chains, and pump-rods, although made of the best iron, would, if subjected to concussion, after a certain time, break suddenly, and that the fracture would exhibit a large crystalized texture. This was also frequently observed in the broken axles of road carriages, although they were generally made of iron of the finest quality.

Mr. E. Woods had observed the crystalized fracture in all the broken axles on railways which he had seen.

Mr. Hood exhibited some specimens of broken axles, all of which showed a large crystalized fracture; he believed that the iron from

which the majority of them had been made was of the best quality, and in the parts not immediately subjected to concussion the fracture was quite different. One of them had been in use only three months, and had become so brittle, that, on attempting to break it, it jarred off the shoulder of the journal, although an incision was made all round at the spot where it was intended to be broken.

Mr. York would account for the tendency of the axles to break at the journal, by that part being subjected, during the process of forging, to more hammering than the body.

Mr. Hood agreed that such might be the case, but he conceived that it was more probably produced by cold hammering. He had taken a sample from the body of a broken cranked axle, from the Grand Junction Railway, the iron of which was evidently of the best quality; but at the point of fracture, which was certainly at that part where it had been most hammered, the fracture presented a large crystalized texture.

A large anchor, which had been in store for more than a century at Woolwich Dock-yard, and was supposed to be made of extremely good iron, had been recently tested as an experiment, and had broken instantly with a comparatively small strain; the fracture presented very large crystals. In this case, he believed the length of time which the anchor had remained in the same position had produced the same effects as magnetism and vibration.

Mr. Lowe stated that at the gas-works under his direction, wrought iron fire-bars, although more expensive, were generally preferred; a pan of water was kept beneath them, the steam from which would speedily cause them to become magnetic. He had frequently seen these bars, when thrown down, break into three pieces, with a large crystalized fracture.

Mr. Miller had frequently seen, in manufactories, that when the smiths had forged parts of engine-work which, from their intricate forms, required to be much hammered, the ends were jarred off while they were being worked upon. He instanced particularly the side rods of the engine for the "Lord Melville" steamer, of which, while shutting up the middle, one of the ends of each rod was jarred off, and presented large crystals in the fracture; being well assured of the good quality of the iron in the rods, he had the same welded on again, and, although the circumstance had occurred twenty years since, they were still at work, and had not shown any symptoms of weakness. It must be evident that, in this case, the fracture and the crystalized appearance of the metal must have been produced by the cold hammering to which it had been subjected.

Mr. York agreed with Mr. Hood in the fact of a change taking place in the texture of the iron, but he was of opinion that it more frequently occurred during, than after, manipulation; he alluded more particularly to railway axles, in which he believed the injury to be done by the cold hammering, or planishing, after they were faggoted; he had frequently seen one end of an axle fall off while the other was being hammered. In all such cases, and in those of accidental break-

age, such as recently occurred on the Versailles Railway, and in other places, the fracture always presented a crystalized appearance.

He then exhibited and described a railway axle, which he stated to possess the combined advantages of rigidity and toughness, and avoiding entirely the crystalization of the iron during the process of manufacture; this he described to be effected by maintaining the axle in a hollow state during the whole operation of hammering, thereby avoiding the vibration and concussion, to which cause he attributed the crystalization of the iron in solid axles, being of opinion that the repeated blows of the hammer on a solid mass, particularly during the process of "planishing," were the chief, if not the only, cause of the ductile quality of the iron being destroyed. He stated that he had made numerous experiments for the purpose of ascertaining this fact, and in every instance, when the axle was sound, the iron presented the same crystalized fracture, although the bars, previous to their being welded together, were of the most fibrous quality; but, if the axle was not quite sound, and the bars not perfectly welded to the centre, then the fracture was somewhat fibrous, the axle being partially hollow, and thereby avoiding the vibration to a considerable extent. This fact suggested to him the propriety of keeping the axle hollow; and the mode of manufacture he described to be by taking two dished half-cylindrical bars of iron, of the entire length of the axle, putting them together, and welding them under a hammer in swages, by which means the particles are not driven asunder by the heavy blows, and the axle, or faggot, lengthened, but are driven together, and towards the centre. The axles produced by this means, he stated to be as perfectly ductile as the bars in the first instance. A further advantage he stated to consist in being able to make half the whole length of the axle at one heat, thereby avoiding, to a considerable extent, the danger of burning the iron by repeatedly heating it; the iron in the axle he described as being an uniform cylinder in thickness, and, consequently, requiring an uniform heat, whereas the external bars of a faggot for a common axle were liable to be burnt, before the centre was heated to a welding state. The diameter of the hollow axle was increased from 3½ inches (the general size of a solid axle) to 4 inches, in order to give a proper degree of rigidity, but without increasing the weight.

The usual proof to which solid railway axles were subjected, was by allowing a weight of six cwt. to fall upon them from a height of nine feet; with that force they were frequently broken at the second blow, and sometimes by the first—he had tried some of the hollow axles, by letting fall upon them a weight of ten cwt. from a height of fifteen feet, without breaking one of them. Edin. N. Philos. Jour.

The Practice of Fresco Painting.

Extracts from Appendix to Report of Commissioners on Fine Arts, for decorating the new House of Commons.

[Continued from Page 62.]

Various Communications on Fresco Painting.

The following papers contain further information respecting the practice of fresco painting, or point out the sources where the subject is more fully treated. In inserting these communications and extracts, it has not been possible to avoid occasional repetition; but, in some cases, coincident testimony may be necessary to establish or recommend particular methods. While the question respecting the adoption of fresco remains, for the reasons before stated, undecided, it may appear premature to describe its methods so fully; but it is precisely because so little is generally known of the process in this country, that it has been thought desirable to take this means of putting the artists and the public in possession of the information that has been collected.

A communication on fresco by Professor Hess, of Munich, (to Mr. William Thomas,) need not be given at length, as it agrees generally with the foregoing statements by Director Cornelius. In speaking of the preparation of the wall, Professor Hess recommends "bricks well dried, and of equal hardness," as the groundwork of the mortar and plaster. Mr. Thomas observes, "all the frescos in Munich are painted on the (plastered) brick wall: laths, with wattling and copper nails, are not approved of, as the risk of bulging is thus increased. The use of laths is sometimes necessary for certain surfaces, but the professors in Munich are decided that a brick ground is to be preferred wherever it is practicable, not only on account of its solidity, but also because it is better adapted for the execution of the painting. The brick ground absorbs superfluous water, and keeps the plaster longer in a fit state for painting upon. The painting ground dries much quicker on laths, as two surfaces are presented for evaporation. The walls ought to be thoroughly dry. A wall of a brick, or a brick and a half, in thickness, is preferable to paint upon. Professor Hess once observed to me, that where the walls in the lower portions of buildings were five or six feet thick, the liability of saline matter making its appearance was much increased, as the mass of wall remains longer in a humid state."

Mr. C. H. Wilson, professor of ornamental design in the Royal Edinburgh Institution, has contributed much useful information on the subject of fresco, derived from his own observation in Italy, and from recent communication from his father, Mr. Andrew Wilson, now at Genoa. He observes: "In Italy, the practice of lathing *walls* is unknown, but many of the finest Italian *ceiling* frescos are on lath, and are in perfect condition. Most vaulted ceilings in what is termed the *piano nobile*, or principal floor of every palace, are constructed of wood. The lathing, in this case, is not attached to single thin pieces of timber, cut to the shape of the ceiling, but to a strong grating; in

some cases, the ribs and transverse pieces of this grating are four inches thick each way. The lathing in Italy is a very peculiar process. The material is the reed, which is cultivated so extensively in that country, and used in so many ways. It grows to the length of about eighteen feet, and is rather more than one inch and a quarter diameter at the base. When these reeds are used for lathing, they are split, and, not being strong enough for the purpose in this state, they are wattled upon the grating. The result of this somewhat complicated contrivance is a framework of great strength."

Mr. Hamilton, a distinguished architect of Edinburgh, observes:—"In the preparation of walls and ceilings for fresco painting, no expense should be spared; battens and lath are obviously perishable materials, and therefore ought to be avoided. The damp from exterior stone walls may be guarded against by lining them with brick; and, now that the use of cast iron is so well understood, the girders, or joisting, of houses where fresco painting is contemplated, should be of iron, arched with brick between, and thus a perfectly level ceiling may be formed of the most durable kind." For the more effectual prevention of damp, Mr. Hamilton recommends that the lining of brick should be somewhat detached, leaving a small space between it and the stone wall, to which it could be bound at intervals. Mr. C. Wilson, in communicating this opinion, remarks, that as the brick lining, added to walls of sufficient solidity for the support of the ceiling here described, would diminish the size of the rooms, tiles placed edgewise might be used instead of bricks. These should, however, be of sufficient strength to be in no danger of fracture from any ordinary accident. To guard against damp from roofs, or even occasional washing of upper floors, it is also suggested that a coating of asphalte might be applied on the upper sides of the arches of the ceiling. In some cases, asphalte might be necessary in walls. Mr. C. Wilson observes, that a French architect, M. Polonceau, effectually checked the progress of damp from a humid soil, in several instances, by covering the horizontal surface of the masonry, a few inches above the level of the soil, with a coating of liquid asphalte, applied with a brush; when this was dry, it was covered with a layer of coarse dry sand, and the building then proceeded. An external joint of hard asphalte at the same level is necessary effectually to cut off all communication of damp. (See the "Revue Générale de l'Architecture," Septembre, 1841.) These and other remarks on the construction of walls and ceilings have been communicated with all deference to the judgment and experience of the architect of the new buildings at Westminster.

In considering the question respecting the comparative fitness of laths and bricks, as a groundwork for fresco, it is not to be forgotten that the battened wall sooner adapts itself to the temperature of the atmosphere, and is, therefore, less likely to be affected by external damp; while the coldness of the more solid wall causes the rapid condensation of moisture in humid weather. This evil might be guarded against by due precautions with regard to temperature and ventilation.

Mr. C. Wilson next describes the mode of preparing the lime at Genoa: "The lime having been slaked is mixed in a trough, about six feet in length and twenty inches in width; at the bottom it is somewhat narrower. The instrument used in mixing it is similar to that used by our masons. The lime is worked with this, and water is thrown in till the substance is of the consistence of cream. At the end of the trough there is a little sluice, the opening of which, however, comes only to within an inch and a half of the bottom of the trough. On being drawn up, the sluice allows the lime to escape, but small stones, or impurities, which may have sunk to the bottom, are prevented from passing by the ledge under the opening. The lime is received in a pit dug in the mere earth, (not lined,) to the depth of several feet, and of any convenient size. The process of mixing in the trough is repeated till the pit is well filled, the trough being washed out with clean water every third or fourth mixing.

"The lime, being thus prepared, is left in the pit from *eight to twelve months*,* according to its ascertained strength. The lime for the first rough coat need not be kept more than two months; this is allowed to dry perfectly, before the next coats are put on. The proportion of sand to lime is the same as with us, viz., two of sand and one of lime. No hair is used by the Italian plasterers. The lime of which the *intonaco*, or coat of fine plaster, is composed, is, however, to be subjected to a much more careful preparation than that used for the first coat. After it has been kept the requisite time, it is taken out with a spade, the greatest care being necessary not to come too near the edges, sides, or bottom, of the pit, lest any clay, or earth, should be taken up with the lime. It is now thrown again into the troughs, and is again thoroughly mixed with water, till it is not thicker than milk; it is then allowed to escape as before through the open sluice, but this time it passes through a fine hair sieve into an earthenware jar; a number of these jars are required, and each is filled to within a third of the top. The lime is allowed to settle, and, when the water which rises over its surface is clear, it is poured off. This is repeated till there is no more water to pour off, and the lime remains in the jar of the consistence of the white paint commonly used, and is quite as smooth. It is now ready to be mixed for the *intonaco*, which consists, as usual, of two parts sand and one of lime. Great pains are taken in Italy to find a suitable sand; it must be perfectly clean, sharp sand, the grains of equal size, and its color favorable, as the *intonaco* should not be too dark. The presence of any earthy particles in the plaster would inevitably ruin the fresco; this accounts for the very careful preparation which all the materials used undergo."

Professor Hess recommends avoiding the intermixture of plaster of Paris in the mortar for the first rough coat, (in the finer coats it is never employed as a preparation for fresco,) and advises a moderate use of small flint pebbles. The rough coat should not be too com-

* In Florence, where fresco painting is now occasionally practiced, artists are of opinion that "the lime should be kept in the moist state from eight to twelve months, otherwise it will burn both colors and brushes." (Letter from Mr. Seymour Kirkup, Florence, 1842.)

pactly laid on, as its porousness is essential to the convenience of fresco painting. In like manner, the last finer coats should be lightly floated on to ensure their power of absorption. He proceeds: "The plaster for painting on is composed of lime, not in too caustic a state, and pure quartz sand. With regard to the lime, it should be well and uniformly manipulated, and should be entirely free from any small hard lumps. The sand should be very carefully washed, to cleanse it from clayey or saline particles, and should be afterwards dried in the open air. Sand that is coarse, or unequal in grain, should be sifted; thus the plaster will be uniform in its texture. The proportion of sand to the lime is best learned from experience, and must depend on the nature of the lime. If the plaster contains too much lime, it becomes incrusted too soon, is too smooth in its surface, and easily cracks; if it contains too little, it is not easily floated, the successive patches (as the fresco proceeds) are not to be spread conveniently in difficult situations, and the plaster is not so lasting."

"Before laying on the plaster, the dry rough coat is wetted with a large brush again and again, till it will absorb no more. Particular circumstances, such as spongy bricks in the wall, humid or very dry weather, &c., dictate the modes in which this operation is to be regulated. The plaster should be laid on lightly and freely with a wooden hand-float; in connecting the successive patches, some portions require, however, to be finished with an iron trowel; in this case, care must be taken not to press too strongly, otherwise rust spots might appear in the lime, and even cause portions of the superadded painting to become detached. [A glass float seems to be preferable where a wooden instrument is unfit.] The plaster should be about a quarter of an inch in thickness. The surface of the last coat is then slightly roughened, to render it fit for painting on. The wall, thus prepared, is to be left a quarter, or half, an hour before beginning to paint."

The colors enumerated by Professor Hess are the following:— "White: lime which has either been long kept, or, by repeated manipulations and drying, is rendered less caustic. Yellow: all kinds of ochres, terra di Siena. Red: all kinds of burnt ochres, burnt terra di Siena, [the brightest particles selected at different stages of the process of burning, furnish, according to Director Cornelius, very brilliant reds,] oxides of iron, and lake-colored burnt vitriol. Brown: umber, raw and burnt, and burnt terra vert. Black: burnt Cologne earth, which, when thus freed from its vegetable ingredients, affords a pure black. Purple: burnt vitriol, cobalt blue, and lake-colored burnt vitriol. Green: Verona green, (terra vert,) cobalt green, and chrome green. Blue: ultramarine, cobalt, and the imitation of ultramarine; the last is most safely used for flat tints, but does not always mix well with other colors. These colors have been well tested, and for the most part admit of being mixed in any way. Other more brilliant colors, such as chrome yellow, vermilion, &c., have been tried in various ways, but have not yet, in every case, been found to stand. Colors prepared from animal and vegetable substances cannot be used at all, as the lime destroys them." Fresco painters observe

that "great attention is necessary in the due preparation of tints on the palette, for, if tints are mixed as the work proceeds, the painting, when dry, will appear streaky; when the colors are wet, the differences are not so perceptible."

In addition to hog's hair tools, which, as before observed, are longer than those used in oil painting, "small pencils of otter hair, in quills, are used. No other hair resists the lime, but becomes either burnt, or curled. The palette, of the material and form before described, is covered with a light colored varnish, to protect the tin from rust. Rain water, (that has not passed through an iron tube,) boiled or distilled water should be used, from first to last, in all the operations of fresco painting."

Professor Hess continues: "After the painter has laid in his general color, he should wait half an hour, or an hour, accordingly as the color sets, before he proceeds to more delicate modeling. In these first operations, he should avoid warm or powerful tints, as these can be added with better effect as the work advances. After the second painting and another pause, the work is finished with thin glazings and washings. Thus the requisite degree of completion can be attained, provided the daylight, and the absorbing power of the plaster, last. But, if the touches of the pencil remain wet on the surface, and are no longer sucked in instantaneously, the painter must cease to work, for henceforth the color no longer unites with the plaster, but, when dry, will exhibit chalky spots. As this moment of time approaches, the absorbing power increases, the wet brush is sucked dry by mere contact with the wall, and the operation of painting becomes more difficult. It is, therefore, advisable to cease as soon as these indications appear."

"If the wall begins to show these symptoms too soon, for example, in the second painting, some time may be gained by moistening the surface with a large brush, and trying to remove the crust, or setting, that has already begun to take place; but this remedy affords but a short respite. In the additions to the painting on successive days, it is desirable to add the new plaster to that part of the work which is not quite dry, for, if added to dry portions, the edges sometimes exhibit spots. Various other effects sometimes take place from causes that cannot be foreseen, and the remedies must be provided by the ingenuity of the artist, as the case may require."

The following extract from a letter addressed by Mr. Andrew Wilson to his son, (in March last,) will render the process of painting in fresco more intelligible; but it is almost needless to observe, that, in such details, the practice of painters may vary considerably.

"I lately went to the royal palace (Genoa) to see the Signor Pasciano paint a ceiling in fresco. His tints had all been prepared before my arrival; he had only two in pots, viz., pure lime, and a very pale flesh tint. He had no palette, but a table with a large slate for the top; on it he set round, 1. Terra vert. 2. Smalt. 3. Vermilion. 4. Yellow ochre. 5. Roman ochre. 6. Darker ochre. 7. Venetian red. 8. Umber. 9. Burnt umber. 10. Black. These colors were all pure, mixed only with water, and rather stiff; put down with a

palette knife, perhaps about an ounce, or two at most, of each. He mixed each tint as he wanted it, adding to each from the pot of flesh tint, or that of white. Near him lay a lump of umber, and, on taking up a brushful of color, he touched this with it; the earth instantly absorbed the water, and he was thus enabled to judge of the appearance which the tint would present when dry. The painter used a resting-stick with cotton on the top, to prevent injury to the *intonaco.* The *intonaco* being prepared in the manner which I have described, the moment it would bear touching, he set to work. The head was that of the Virgin; he began with a pale tint of yellow round the head for the glory, (the color of the ground, owing to the mixture of sand with the lime, it is to be remembered, is a cool middle tint;) he then laid in the head and neck with a pale flesh color, and the masses of drapery round the head and shoulders with a middle tint, and with brown and black in the shadows. He next, with terra vert and white, threw in the cool tints of the face; then, with a pale tint of umber and white, modeled in the features, covered with the same tint where the hair was to be seen, and with it also indicated the folds of the white veil. All this time he used the colors as thin as we do in water colors; he touched the *intonaco* with great tenderness, and allowed ten minutes to elapse before touching the same spot a second time. He now brought his colored study, which stood on an easel, near him, and began to model the features, and to throw in the shades with greater accuracy. He put color in the cheeks, and put in the mouth slightly, then shaded the hair and drapery, deepening always with the *same* colors, which became darker and darker every time they were applied, as would be the case on paper, for instance. Having worked for half an hour, he made a halt for ten minutes, during which time he occupied himself in mixing darker tints, and then began finishing, loading the lights, and using the colors much stiffer, and putting down his touches with precision and firmness; he softened with a brush with a little water in it. Another rest of ten minutes; but, by this time, he had nearly finished the head and shoulders of his figure, which, being uniformly wet, looked exactly like a picture in oil, and the colors seemed blended with equal facility. Referring again to his oil study, he put in some few light touches in the hair, again heightened generally in the lights, touched too into the darks, threw a little white into the yellow round the head, and this portion of his composition was finished, all in about an hour and a half. This was rapid work; but you will observe that the artist rested *four times,* so as to allow the wet to be sufficiently absorbed into the wall to allow him to repass over his work."

"The artist now required an addition to the *intonaco;* the tracing was again lifted up to the ceiling, and, the space to be covered being marked by the painter, the process was repeated, and the body and arms of the Madonna were finished before I left him, at one o'clock."

The following is an extract from a second letter:—"Yesterday I went again to see Pasciano, and I found that he had cut away from his tracing, or cartoon, those parts which he had finished upon the ceiling; in fact, I now found it cut into several portions, but always

carefully divided by the outline of figures, clouds, or other objects. These pieces were, in some instances, a good deal detached from each other, and were nailed to the plaster, so as to fold inwards, or outwards, for pouncing the outlines. The *intonaco* had just been fresh laid for the upper half of an angel supporting the feet of the Madonna. This was one of a group much larger than those surrounding the glory, and, therefore, requiring more color and finish; more than half of the figure, too, was in shadow, with a strong ray of light on the face and on one of the arms: this was a good opportunity of observing the painter's management of shadow. Having gone over the outline carefully with a steel point, he waited till the *intonaco* became a little harder, and, in the mean time, mixed up a few tints; he then commenced with a large brush, and went over the whole of the flesh; he next worked with a tint which served for the general mass of shadow, for the hair, and a slight marking out of the features. He now put a little color into the cheeks, mouth, nose, and hands, and all this time he touched as lightly as he possibly could, not to wash up the *intonaco*. He then halted for ten minutes, looking at his oil study, and watching the absorption of the moisture; and he called my attention to his outline—none of it was effaced by this washing.

"The *intonaco* would now bear the gentle pressure of his fingers, and, with the same large brush, but with water only, he began to soften and unite the colors already laid on. Observe, he had not as yet used any tint thicker than a wash of water color, and he continued to darken in the shadows without increasing the force, or depth, of color. This I before noted to you, that you can strengthen by the simple repetition of tint; but, if the day be very dry, after an hour or two this process of repeating with the same tint produces an opposite effect, and, instead of drying darker, it actually dries lighter. [See this explained in the communication by Professor Hess.] I now observed that the painter had increased the number of his tints, and that they were of a much thicker consistence; and he now began to paint in the lights with a greater body of color, softening them into the shades with a dry brush, or with one a little wet, as he required. In drying, the water comes to the surface, and actually falls off in drops; but this does no harm whatever to the work, although it sometimes looks alarming."

Mr. C. Wilson observes that the Aurora of Guido, in the Rospigliosi palace, in Rome, was painted on a copper trellis, and afterwards fixed on the ceiling, where it still exists. He adds that this fresco was offered for sale about fifteen years since, and that its safe removal was guaranteed. Mr. W. Thomas states that some small (landscape) frescos by Professor Rottman, in the Hofgarten in Munich, were painted on an iron frame and wire-work, and fixed in their situation afterwards. The example of Guido's Aurora, the figures of which are larger than life, shows that it would be possible to prepare movable frescos for situations where this might be thought necessary—for example, before flues, or tubes, in walls. But it is to be remarked that flues behind frescos have generally injured them. Mr. Aglio, who painted some frescos at Manchester some years since, attributes the

great alteration of the colors in them, partly, to this circumstance, but also to his having been supplied with lime that was much too fresh. Cavaliere Agricola, in examining the frescos of the Vatican, found that the "Heliodorus" had suffered considerably from a flue behind it. The plaster had been detached from the wall, and projected, in some places, nearly four inches; it had been secured with nails, and the cracks had been filled with some composition, by Carlo Maratti, in 1702. The fresco of the "Defeat of the Saracens at Ostia" has been injured, in like manner, by a chimney behind it.

In connexion with the subject of movable frescos, it may be observed that the operation of detaching the mere painting from the wall, almost independently of the plaster, has been often practiced with success. Although less immediately connected with the present inquiry, it is desirable to make this process known, as, in repairing churches, and other buildings, in England, many ancient paintings on plaster have been destroyed, from ignorance as to the means of removing them. Mr. Ludwig Gruner gives the following account of the mode in which he detached some frescos at Brescia, in 1829. The convent of St. Eufemia, in that city, was then undergoing repair, and the excellent frescos it contained, painted by Lattanzio Gambara, in the sixteenth century, would have been destroyed, when Mr. Gruner succeeded, with the assistance of some expert Italians, in removing them from the walls. The mode they adopted was, first, to clean the wall perfectly; then to pass a strong glue over the surface, and, by this means, to fasten a sheet of fine calico on it. The calico, after having been riveted to the irregularities of the wall,* was afterwards covered with glue in like manner, and on it was fastened common strong linen. In this state heat was applied, which caused the glue even on the fresco to sweat through the cloths, and to incorporate the whole. After this, a third layer of strong cloth was applied on a new coat of glue. The whole remained in this state two or three days, (the time required may vary according to the heat of the weather.) The superfluous cloth extending beyond the painting was now cut off, so as to leave a sharp edge; the operation of stripping, or rolling, off the cloth begins at the corners, above and below, till at last the mere weight of the cloth, and what adhered to it, assisted to detach the whole, and the wall behind appeared white, while every particle of color remained attached to the cloth. This operation shows that the colors in fresco do not penetrate very deeply; the layer of pigment and lime which was detached in this instance was extremely thin—the outlines, and even the colors of masses, were visible at the back of the cloth. It is the opinion of some of the Munich professors that frescos thinly painted are least liable to change; the example just given, exemplifying, as it does, the practice of a skilful Italian fresco painter, seems to confirm this; but, in many instances, the surface of frescos, even by the older masters, is solidly painted. To

* Mr. A. B. Johns, of Plymouth, suggests fastening one or two layers of blotting paper on the surface of the painting at first, not only because that material may be made to adhere more closely to the wall, but because it is more easily detached by moisture, together with the cloths, when the painting is re-transferred to a new surface.

transfer the painting again to cloth, in completing the operation above described, a stronger glue is used, which resists moisture, it being necessary to detach the cloths first used, by tepid water, after the back of the painting is fastened to its new bed.

The frescos by Paul Veronese, in the Morosini Villa, near Castel Franco, were removed by Count Balbi, of Venice, a few years since; he fastened cloth to the wall with a paste composed of beer and flour, and riveted it to the irregularities of the surface by means of a hammer composed of bristles. Several of these works, when re-transferred to canvas, were sold in England in 1838. The operation of removing frescos has been lately performed with success in Florence, and elsewhere.*

(To be continued.)

Comparison between the Strength and Deflection of the Ystalyfera Iron, made with Cold Blast and Anthracite, and some Experiments made with the same Iron, manufactured with Hot Blast. Bars five feet long, one inch square; the supports four feet six inches apart.

	Breaking weight.	Deflection.	Force to resist impact
	lbs.	lbs.	lbs.
Ystalyfera cold blast iron, from furnace,	618½	1.988	1297
" hot blast iron, re-melted as per Mr. Evans' second table of experiments,	496	1.632	821
Cold blast stronger than hot,	122¼	.356	476
Equal to per cent.	24.6	21.8	57.9
Ystalyfera cold blast iron, re-melted in cupola with anthracite,	674	2.030	1373
" hot blast, re-melted by Mr. Evans	496	1.632	811
Cold blast stronger than hot,	178	.398	562
Equal to per cent.	35.8	24.3	69.25
Ystalyfera cold blast iron, re-melted in air-furnace,	660	1.760	1162
" hot blast, per Mr. Evans,	496	1.632	811
Cold blast stronger than hot,	164	.128	351
Equal to per cent.	33.5	.8	43.25

* The following publications may be consulted for further information on this subject:—Leopoldo Cicognara, del distacco delle pitture a fresco. Articolo estratto dall' Antologia di Firenze, 1825. Vol. 18, num. 52.—Girolamo Baruffaldi, Vita di Antonio Contri, pittore e rilevatore di pitture dal muro. Venezia, 1834.—Cenni sopra diverse pitture staccate dal muro e transportate su tela, &c. Bologna, 1840.

N. B.—I have, to avoid prolixity, taken the middle table of Mr. Evans for reference, as the nearest approach to a correct mean of the qualities of the iron operated on—viz., Nos. 1, 2, and 3. His summary is—

	Breaking weight.	Deflection.	Impact.
Table of No. 1 experiment,	444½ lbs.	1.834	821
" 2 "	496 "	1.632	811
" 3 "	533 "	1.640	916

Having clearly established the superior strength of the Ystalyfera pig-iron, made with cold blast, more particularly in reference to the experiments of Mr. Tredgold, and those of Mr. Evans, I have next abstracted Mr. Fairbairn's Table of General Results, and, as nearly as possible, arranged and divided them into two classes, viz.: Experiments with Hot Blast Iron, and Experiments with Cold Blast Iron. The abstract of results of the hot blast iron, I find to be as follows:

Average breaking weight of the five feet bars, the supports being 4 feet 6 inches apart,	lbs.	445
Average deflection,		1,537
Strength to resist impact,		690
Cold blast—breaking weight,	lbs.	455
" average deflection,		1.612
" strength to resist impact,		734

These results enable me to make the following comparisons:

General average of the Ystalyfera cold blast, five feet bars, in breaking weight,	lbs.	644½
Breaking weight of similar bars, hot blast, from Mr. Fairbairn's table,	lbs.	445
Ystalyfera iron stronger by	lbs.	199½

—equal to 44$\frac{7}{10}$ths per cent.

As there is only 10 lbs. between the breaking weight of the cold and hot blast in Mr. Fairbairn's table, any separate statement of the fact I consider unnecessary.

Ystalyfera cold blast—average deflection of the five feet bars,	lbs.	1.916
Deflection of hot blast iron from Mr. Fairbairn's table,		1.537
Difference in favor of Ystalyfera iron,	lbs.	.379

—equal to 26$\frac{6}{10}$ths per cent.

Ystalyfera cold blast—average deflection,	lbs.	1.916
Deflection of cold blast iron from Mr. Fairbairn's table,		1.612
Difference in favor of Ystalyfera iron,		.304

equal to 18$\frac{8}{10}$ths per cent.

Ystalyfera cold blast iron, in respect to its resisting impact, general average of five feet bars.	lbs.	1235
Hot blast iron from Mr. Fairbairn's table,		690
Difference in favor of Ystalyfera iron, —equal to 79 per cent.	lbs.	545
Ystalyfera cold blast iron, in respect to its capacity to resist impact,		1235
Cold blast iron from Mr. Fairbairn's table,		734
Difference in favor of Ystalyfera iron, —equal to 68 2/10ths per cent.	lbs.	501

From these and the former comparative experiments, it is abundantly evident that the pig iron, now making with cold blast and anthracite, at the Ystalyfera Iron Works, greatly exceeds, in strength, and deflective powers, and capacity to resist impact, any iron at this time manufactured in the United Kingdom. It now only remains for me to mention a property peculiar to the iron, which was noticed at the time I made the trial experiments at Yniscedwyn, four years ago, but which has been more fully developed in those recently made at Ystalyfera. The property referred to is one of great springiness, or elasticity, which communicates a tendency to the bar, in deflecting and breaking, to resume its rectangular form. Bars that had obtained a permanent set of 2-10ths, when afterwards broken, presented but a slight deviation from a right line, and in no case did the acquired curvature exceed one-fourth of a tenth. It was also remarked that most of the fractures, in breaking, presented a regularity of grain throughout, resembling the structure of unhardened steel.

Coleford, Nov. 18. DAVID MUSHET.

Railway Mag.

Experiments on the Explosive Effects of certain Mixtures of Gunpowder and Air. *By* CHARLES THORNTON COATHUPE, Esq.

Sir,—The following experiments, illustrating certain effects produced by the explosion of gunpowder, may be interesting to some of your readers. Being exceedingly fond of rifle-shooting, it so happened, during a morning's practice, that the ball became so fixed in the barrel, at a short distance above the charge of powder, that I could not, with the implements then present, force it "home." I had often heard of guns bursting from similar incidents, but, having duly surveyed the substance of the metal around the bore of the barrel, I thought—*well, this cannot burst.*

The rifle was very small, having two grooves in the barrel, and carrying a ball weighing the 1/88th of a lb. avoirdupois. The charge of powder was 20 grs. of the best quality, ("extra canister;") the target was a wrought iron plate, ¼ inch thick; the distance was 100 yards, and the usual effect upon the target was the slightest possible

indentation of the surface upon which the ball impinged, (the ball being smashed to atoms.)

On this occasion, however, the ball all but perforated the entire substance of the plate. The indentation was deep and conical, bursting open the opposite surface of the plate.

It immediately occurred to me that this unexpected result might be turned to advantage, by making barrels so strong, that, instead of the thus increased force of an ordinary charge of powder being spent in bursting the tube in which it might happen to be exploded, it might be expended in propelling its ball. I therefore had a small cannon manufactured of twisted wrought iron, and bored from the solid mass, leaving the substance of iron around the bore so thick that it could not be injured by any method of exploding gunpowder within it. Its bore was 11 inches long, and its calibre suited a ball weighing $\frac{1}{23}$d of a lb. avoirdupois. It was charged with 56 grs. of Curtis and Harvey's "canister powder," and it was fired at a target composed of eight planks of half-inch elm board, under the following circumstances, each experiment being repeated three times. The distance was ten yards.

			Ball through		and into
1st	average,	powder and ball alone,	5	planks	6th
2d	do.	with air equal half bulk of the powder,	5	"	6th
3d	do.	with air equal whole bulk of the powder,	6	"	7th
4th	do.	with air equal one and a half bulk of the powder,	5	"	
5th	do.	with air equal two bulks of powder,	5	"	(barely.)

It may be asked how I ascertained that the bulks of air included above the powder were precisely such as I have reported them to have been.

In the first place, I prepared some cylinders of cartridge paper, which exactly fitted the bore of the cannon, and, having ascertained the requisite length of one of these cylinders to contain just 56 grs. weight of powder, I divided each cylinder, as it revolved in a lathe upon a wooden mandril, into lengths proportioned to the volumes of air they were intended to contain. Over one extremity of each cylinder thus cut and regulated, I pasted a slip of very thin muslin. In loading, the powder was inserted through a brass tube, the gun being held perpendicularly. The paper cylinder was then slid down upon the powder with the closed end downwards. Above the paper cylinder a piece of mill-board, cut with a gun-punch of the precise diameter of the bore, was inserted, and above this the ball was placed, and retained in its situation by means of a circular piece of thick card. Previous to each discharge, the gun-carriage was fixed firmly to the ground by an iron rod, that any errors from the recoil of the gun might be obviated.

Although these experiments are of too rough a nature to give the exact effect of each discharge, they still afford an ample illustration of the limits within which air can be advantageously combined with gunpowder for practical purposes. It appears that about equal bulks

of air and of powder produce the best results; and this relative proportion of air seems to increase the explosive force of gunpowder by about the one-fifth of that which would have been obtained had the air been altogether excluded. Hence 20 per cent. of gunpowder may be saved, the effects remaining constant; or, the usual charges of powder being retained, their effects may be increased nearly in the ratio mentioned above. This principle may be economically adopted, either for propelling balls, or for blasting rocks. Mech. Mag.

On a Re-arrangement of the Molecules of a Body after Solidification. By Robert Warington, Esq.

Having occasion, lately, to prepare some alloys of lead for the purpose of lecture-illustration, I was much surprised at an alteration taking place in the arrangement of the particles of one of these alloys, as shown by the appearance of the surfaces of fracture, after the metal had assumed the solid form. The alloy experimented on was that known as Newton's fusible metal, composed of eight parts of bismuth, five of lead, and three of tin. On pouring this alloy, in the melted state, on a marble slab, and breaking it as soon as solid, and when it may be readily handled, the exposed surfaces were found to exhibit a bright, smooth, or conchoidal, metallic appearance, of a tin white lustre; and the act of disjunction at one part will, frequently, cause the whole to fly into a number of fragments, analogous to the breaking a piece of unannealed glass.

The metal, after this, becomes so hot as to burn the fingers if taken up; and when this evolution of heat has ceased, the alloy will be found to have entirely altered its characters, having lost its extreme brittleness, requiring to be bent to and fro several times before it will break, and presenting, on fracture, a fine granular, or crystaline, surface, of a dark color, and dull, earthy aspect. Similar phenomena accompany the casting of the fusible alloy of V. Rose, composed of two parts of bismuth, one of lead, and one of tin.

The fact of the evolution of heat from the alloy of Newton, and its cause, are thus noticed by Berzelius, in his *Traité de Chimie*:—"If this alloy is plunged into cold water, and quickly withdrawn and taken in the hand, it becomes sufficiently hot, after a few moments, to burn the fingers. The cause of this phenomenon is, that, during the solidification and crystalization of the *internal parts*, the latent heat of these is set free, and communicates itself to the surface before the fixing and cooling." The alteration in the internal arrangement of the particles, as proved by the surfaces of fracture, is not, however, noticed, and the explanation is defective, as it supposes the interior not to have assumed the solid state until the evolution of the heat occurs. If such were the case, it would be seen on breaking it in the first instance. The phenomena can only be accounted for by admitting a certain degree of mobility among the particles, and that a second molecular arrangement takes place after the metal has solidified.

This may arise from their not having assumed, in the first state, that direction in which their cohesion was the strongest.

That a very marked and extraordinary alteration in the characters and properties of various substances, arises entirely from this change in the position of their component particles, effected either by the communication or abstraction of heat after solidification, there can be no doubt. And these changes are applied to many very important purposes in the arts and manufactures—such as the hardening and tempering of steel, the rolling of commercial zinc, and rendering that metal permanently malleable, the annealing of glass, and a variety of other uses, particularly in crystalization, which might be adduced.

The following experiments were made to ascertain to what extent the emission of latent heat takes place. The melted alloy was poured, in a perfectly fluid state, on the bulb of a thermometer, placed in a small platinum crucible, having a capacity equal to about 70 grain measures of water, and standing in a vessel of cold water, or mercury. The thermometer, surrounded by the solidified metal and crucible, was removed from the cooling medium before it had reached its stationary point, and the greatest decrease of temperature noted. The heat then rose rapidly again, and the maximum effect was registered. The fusing point of the alloy was 202° Fahrenheit, and the following results were obtained:

Exper.			Fahr.		Fahr.	Diff. Fahr.
1	thermometer	fell to	97°	and then rose to	157°	60°
2	"	"	94	"	149	55
3	"	"	90	"	150	60
4	"	"	87	"	147	60
5	"	"	104	"	156	52
6	"	"	97	"	148	51
7	"	"	92	"	152	60
8	"	"	104	"	155	51

So that, in four out of the eight trials, a difference of 60° Fahrenheit was rendered apparent.

In a platinum crucible of larger size the effects were not so marked, 34° Fahrenheit being the greatest difference obtained; this, of course, would arise from the greater bulk of the melted metal not exposing, comparatively, so large a surface to the cooling medium.

Edinb. N. Philos. Jour.

Stone Boring Machine.

Mr. Carnegie presented one of Hunter's stone boring machines to the Institution of Civil Engineers, and explained its action to the meeting.

The machine is composed of two parallel bars of steel, supporting a traversing carriage, through the centre of which passes a spiral auger attached to a screwed bar; this bar fits into a female screw clamp above the carriage, and on the upper end is a winch with four handles.

When the instrument is in use, it is fixed by two cramps upon the stone to be pierced, and the auger, being made to revolve by means of the winch, scoops out, at each revolution, as great a depth of stone as is equal to the distance which the screw descends; the chips, ascending through the spiral channel of the auger, are thrown off at the top. The peculiar shape of the point of the auger prevents its being abraded, as it operates by chipping the stone, and not by grinding it away. This, with the means of forcing it down by the screw, is the chief novelty of the machine. It has been extensively used at the works of the new harbor of Arbroath, by Mr. Leslie, who speaks of it in the following terms:

"Mr. Hunter's boring machine has been advantageously employed for above a year, in boring trenail holes in the stones used at the new harbor of Arbroath. The holes are 1¾ inch diameter, and from nine inches to two feet in depth; the aggregate of the holes already bored amounts to upwards of 30,000 linear feet. The machine may be adapted for boring holes of any dimensions. It does the work considerably cheaper than the 'jumper,' and much more correctly, as it makes the holes perfectly straight, cylindrical, and equal throughout, instead of the irregular form made by the common jumper. This machine is very well adapted for boring railway blocks, and has been much used in this quarter for that purpose. I consider it to be more especially valuable from the facility which it affords of boring and trenailing down the stones used in sea buildings, in any exposed situation; as I have found that trenailing is a great security to such building while in progress, when the upper courses are much exposed, and liable to be washed off, unless they be held down by other means than their own absolute weight.

"The expense of boring the old red sand-stone rock, here, is about three halfpence per linear foot."

Mech. Mag.

Sugar from Maize, &c.

Paris Academy of Sciences, Sept. 12.—A report was read on the production of sugar from maize.—A paper by M. Huan, on the means of preventing accidents on railways by the breaking of an axletree. The invention consists of such a modification of the wheel of the locomotive, that if the axle should break, the wheel itself becomes an axle, and prevents further accident.—M. Arago, in allusion to the opinion expressed by several persons as to the electricity of whirlwinds, mentioned to the Academy some observations made by M. Hortola on a storm, on the 24th ult., in the department of the Aude. This gentleman relates that, on the occasion referred to, the iron bars of windows, the gutters of sheet iron, the plates of insurance companies, and other metallic objects, were carried away by the whirlwind, thus indicating the presence of electricity.

Lond. Athenæum.

Photography. *By* Sir JOHN HERSCHEL.

The preparation of the chrysotype paper is as follows: dissolve 100 grains of crystalized ammonio-citrate of iron in 900 grains of water, and wash over with a soft brush, with this solution, any thin, smooth, even-textured paper. Dry it, and it is ready for use.

On this paper a photographic image is very readily impressed, but it is extremely faint, and, in many cases, quite invisible. To bring out the dormant picture, it must be washed over with a solution of gold in nitro-muriatic acid, exactly neutralized with soda, and so dilute as to be not darker in color than sherry wine. Immediately the picture appears, but not at first of its full intensity, which requires about a minute, or a minute and a half, to attain, (though, indeed, it continues slowly to darken for a much longer time, but with a loss of distinctness.) When satisfied with the effect, it must be rinsed well two or three times in water, (renewing the water,) and dried.

In this state it is half fixed. To fix it completely, pass over it a weak solution of hydriodate of potash, let it rest a minute or two, (especially if the lights are much discolored by this wash,) then throw it into pure water till all such discoloration is removed. Dry it, and it is thenceforward unchangeable in the strongest lights, and (apparently) by all other agents which do not destroy the paper.

The other process is as follows: mix together equal parts of the solution of the above-named salt, and of a saturated solution of, not the ferrosesquicyanate of potash, (as stated in the Athenæum,) but the common yellow ferrocyanate, or, as it is called, prussiate of potash. The result is a very black ink, which, washed over paper, gives it a deep violet-purple color, and is remarkably sensitive to light—whitening rapidly, and giving positive pictures—the only defect of which (and it is a fatal one for use) is their want of durability, as they fade with darkness in a few hours. And, what is very singular, the *same paper* is again and again susceptible of receiving another and another picture, which die away in like manner, without any possibility, so far as I have yet discovered, of arresting them. Ibid.

English Patents.

Specification of the Patent granted to WILLIAM HENRY FOX TALBOT, *of the County of Wilts, for Improvements in Coating, or Covering, Metals with other Metals, and in Coloring Metallic Surfaces.* Sealed December 9, 1841. Enrolled June 9, 1842.

To all to whom these presents shall come, &c.—The first part of my invention consists of adding gallic acid to the metallic solution intended to be precipitated. I take any convenient solution of silver, gold, or platina, and I add to each of them a solution of gallic acid in

water, ether, or alcohol, which latter I consider preferable. Into any one of these mixtures I then immerse a clean bright plate of metal, until it becomes coated (as the case may be) with silver, gold, or platina. I find it best, in general, to begin with a weak, or dilute, solution, and afterwards to use a stronger one. The gallic acid need not be pure; but cheaper liquids, containing a considerable portion of it, or of an analogous vegetable substance, may be used instead of the pure acid. With respect to this part of my invention, I claim the use of gallic acid, or liquids containing it, or an analogous vegetable substance, for facilitating the precipitation of metals upon other metallic surfaces, and coating them therewith. The next part of my invention is a method of silvering metallic surfaces. For this purpose I dissolve freshly precipitated chloride of silver in hypo-sulphate of soda, or any other liquid hypo-sulphate, which I believe to be the only class of bodies, hitherto discovered, which have the property of dissolving chloride of silver freely and abundantly. Into this solution I then immerse a clean bright plate of metal, and it is very rapidly coated with a bright silver coating. In order to obtain thicker coats of metal, I employ a galvanic battery in the way now well known, using one of the liquids described in the first and second parts of this specification, and employing for one of the poles, or electrodes, a piece of metal of the same kind as that which is intended to be precipitated. With respect to this part of my invention, I claim the use of hypo-sulphate of soda, or other liquid hypo-sulphate, for the silvering of metals, and the employing a galvanic battery for obtaining thicker deposits of silver, gold, or platina; but I claim this only when used in conjunction with one of the liquids above described. The metals which may be coated with other metals, by the processes above described, are brass, copper, German silver, and also (though less effectually) iron and steel.

The next part of my invention is a method of ornamenting surfaces of brass, or copper, by first gilding them partially according to some pattern, and then washing them over with a solution of chloride of platina, which has no action on the gilt parts, but gives a dead black appearance to the rest of the surface, thus enhancing the brilliancy of the parts which are gilt.

The last part of my invention is a method of coloring polished surfaces of copper, by exposing them to the vapor of sulphuretted hydrogen, or of any of the liquid hydro-sulphurets, or to the vapors of sulphur, iodine, bromine, or chlorine, or by dipping the metal into liquids containing them; but I prefer to use the hydro-sulphurets as above mentioned. By this means, very brilliant colors are obtained on the copper, and, by partially protecting the surface of the metal, according to any determinate or ornamental pattern, very pleasing effects are produced, exhibiting great contrast of colors in a little space. As it is easy to render the copper nearly white by the method above described, I employ it for obtaining metallic specula, or mirrors, as follows. I take an electrotype cast in copper from a polished plane, or spherical metallic surface, which cast has nearly the same degree

of polish as the original, and I then expose it to the action of vapors, as above described, until it is sufficiently whitened, which is effected without injuring the polish. As the surface of the speculum thus obtained is already combined chemically with sulphur, or one of the other bases, or substances, above mentioned, it is consequently less liable to tarnish, or oxydate, subsequently, by any exposure to the atmosphere. With respect to this last part of my invention, I claim the coloring of copper surfaces by exposing them to the chemical action of the above-named substances. Rep. Pat. Inv.

Specification of a Patent granted to EDWARD BROWN, *of the county of Glamorgan, for a new Principle, applied to the Roasting and Refining of Copper.* Sealed 22d June, 1839. Enrolled December, 1839.

The patentee commences his specification by observing, that the usual process which the ore is required to undergo, in order that the copper may be separated from the impurities with which it is combined in the mineral state, are six in number, viz.: first, calcining the ore; secondly, smelting the calcined ore; thirdly, calcining the coarse metal; fourthly, smelting the calcined metal; fifthly, roasting the metal; and, sixthly, refining and toughening it.

The invention relates to the last two processes, and comes into operation when the coarse, or blistered, copper is in a state of fusion in the reverberatory furnace, covered by the slag, or scoria, made in the process of roasting the metal.

Upon the fused metal a flux is thrown, composed of equal parts of quick-lime and anthracite, or other, coal; or of equal parts of lime and wood charcoal, finely powdered. This is stirred in, by means of an iron rable, until the scoria, which was previously of a red color, is changed into a black, frothy mass; it is then skimmed off the surface of the metal, which is afterwards tapped into the sand-bed. The quantity of flux required is from half a bushel to a bushel for each charge of metal.

The blistered copper is now put into the refining furnace, and further roasted and melted until it becomes pure, and ready to undergo the improved toughening process, which consists in covering the surface of the metal with a mixture of equal parts of finely-sifted lime and pulverized wood charcoal, or of lime and saw-dust, or lime and anthracite coal, coarsely powdered, (polling the metal as usual;) the quantity required, at the commencement of the polling, being about three Winchester bushels; an addition is afterwards made, if necessary, in order to preserve the surface of the metal from exposure to the air that passes through the furnace. By this process, the remaining portion of sulphur, and other impurities, which are inseparable from the copper by the ordinary method, are effectually removed, and the metal becomes highly ductile and malleable.

The patentee claims the application, or use, of any portion of lime, in combination with any other matters, or substances, whatsoever, in roasting, or in refining, copper ores. Lond. Jour. Arts & Sci.

Specification of a Patent granted to THOMAS WILLIAM BOOKER, *of Melin Griffith's Works, near Cardiff, for Improvements in the Manufacture of Iron.* Sealed 22d February, 1841. Enrolled August, 1841.

These improvements consist in accelerating the operation of converting cast-iron into malleable iron. It consists in running off the metal, in a fluid state, after the refining process is complete, from the refinery into the puddling furnace, through a passage that connects the two furnaces. The metal is then puddled, and divided into lumps, or balls, as usual, in readiness for passing between the rolling cylinders, or other apparatus used for compressing, or forging, the iron.

Ibid.

Meteorological Observations for November, 1842.

Moon.	Days.	Therm. Sun Rise.	Therm. 2 P.M.	Barom. Sun Rise.	Barom. 2 P.M.	Wind. Direction.	Wind. Force.	Water Fallen in rain	State of the Weather, and Remarks.	
	1	38°	59°	30.24	30.15	W.	Moderate		Hazy.	Hazy.
⊗	2	45	56	30.15	30.15	E.	do		Hazy.	Hazy.
	3	36	48	29.80	29.80	NE.	do		Clear.	Clear.
	4	31	48	29.78	29.70	W.	do		Clear.	Clear.
	5	36	55	29.70	30.65	W.	Calm		Clear.	Hazy.
	6	41	67	29.95	29.96	W.	do		Clear.	Hazy.
	7	44	63	29.86	29.80	S.	do		Par. cloudy.	Hazy.
	8	49	49	29.35	29.30	NE.	Moderate	1.60	Rain.	Rain.
☾	9	47	57	29.55	29.55	W.	do	.04	Cloudy.	Rain.
	10	36	47	29.80	29.80	W.	Brisk		Cloudy.	Flying clouds.
	11	36	48	30.00	30.00	W.	do		Clear.	Par. cloudy.
	12	38	46	30.10	30.10	E. S.	do	.15	Rain.	Cloudy.
	13	36	46	29.98	30.00	SW.	do		Clear.	Clear.
	14	35	44	29.95	29.95	NE.	Moderate		Flying clouds.	Cloudy.
	15	34	44	29.90	29.90	W.	do		Clear.	Clear.
	16	34	49	29.80	29.80	NE.	do	.03	Snow.	Cloudy.
⊗	17	38	46	29.85	29.75	E. SE.	do	.77	Cloudy.	Rain.
	18	47	37	29.30	29.35	W.	Blustering		Cloudy.	Clear.
	19	25	38	29.70	29.80	W.	do		Clear.	Clear.
	20	24	35	30.10	30.10	W.	Moderate		Clear.	Clear.
	21	24	36	30.15	30.15	W.	do		Clear.	Cloudy.
	22	21	35	30.15	30.14	W.	do		Par. cloudy.	Par. cloudy.
	23	23	38	30.14	30.10	W.	Calm	.08	Clear.	Rain.
	24	23	42	29.75	29.80	W.	Brisk		Cloudy.	Clear.
☽	25	25	39	30.10	30.10	W. SW.	Moderate		Clear.	Clear.
	26	25	39	30.11	30.14	W.	do		Clear.	Clear.
	27	30	28	29.63	29.55	W.	Brisk		Cloudy.	Clear.
	28	18	28	30.10	30.10	W.	Moderate		Clear.	Cloudy.
	29	16	30	30.25	30.30	W.	do		Clear.	Clear
	30	23	28	30.15	29.74	E.	do	.80	Cloudy.	Cloudy—snow.
		32.60	44.17	29.91	29.93			3.47		

Thermometer.		Barometer.	
Maximum 67 on 6th. Minimum 16 on 29th.	Mean 38.385	Max. 30.65 on 5th. Min. 29.30 on 8th & 18th.	Mean 29.92